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SPECIAL PROJECTS GROUP
Technical Report No. 112

STRESS ANALYSIS OF 1/12 SCALE HOVERING AND TRANSITION MODEL

September 1957

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| DWG. N° | DESIGNATION |
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| 1-SK-30290 | Installation of $\frac{1}{12}$ scale model and balance in 20' tunnel |
| 4-SK-30290 | G.A. of instrumentation |
| 6-SK-30290 | G.A. of Calibration rig |
| 7-SK-30290 | Ass'y details of rear load member and fairing to control arm and fairing. |
| 8-SK-30290 | Attachment of main ass'y supply pipes to tunnel front load members |
| 10-SK-30290 | G.A. of model |
| 15-SK-30290 | Ass'y of load gauges and supply pipes to model |
| 41-SK-30290 | Main ass'y of supply pipes |
| 355-SK-30290 | Fairing assembly. |
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELINDEX OF REFERENCES.AVRO SPECIAL PROJECT GROUP TECHNICAL REPORTS.

AVRO/SPG/TR 29 : AIR CUSHION EFFECT TESTS - PART 2
AVRO/SPG/TR 33 : AIR CUSHION EFFECT TESTS - PART 3
AVRO/SPG/TR 98 : TEST SPECIFICATIONS FOR THE $\frac{1}{12}$ SCALE
HOVERING & TRANSITION MODEL.

GENERAL REFERENCES.

- AN-C-5. - MARCH 1955 -
- THEORY OF PLATES & SHELLS - S. TIMOSHENKO.
- RESISTANCE DES MATERIAUX APPLIQUEE A L'AVIATION - P. VALLAT.
PUBLISHED BY : MENARD - EDEURS - 8 RUE DES REGANS - TOULOUSE - FRANCE.

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The strength and stiffness of the $\frac{1}{12}$ scale hovering and transition model, its supporting structure and fairings are analyzed.

The stressing of all parts except the ring load gages is carried out with an ultimate load factor of 4.

The strength of all components has been found satisfactory and the deflections small enough to be negligible.

Balance calibration procedure is outlined and pertinent data provided.

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As a part of the system 606 A test program, a $\frac{1}{12}$ scale model of the P.V. 704 aircraft has been designed for installation in the 20' diameter Mearns Memorial Wind Tunnel at Wright-Patterson Airforce Base. The purpose of the model is to study the take-off, hovering and transition to forward flight characteristics of the aircraft. The proposed tests are outlined in AVRO/SPG/TR 98 - Test Specifications for the $\frac{1}{12}$ scale Hovering and transition model. The development of loads, and the stressing of the model, model support structure and fairings are contained in this report.

The model is circular in planform: 35.3" DIA, with intake and jet exhaust flows simulated. These flows are supplied through large diameter pipes which also serve to support the model on the wind tunnel balance. In order that the balance is not affected by the supply pressures, these pipes come into the tunnel in a horizontal plane to supply the vertical pipes supporting the model.

The wind tunnel balance is a three components balance measuring lift, pitching moment and drag. However, due to the distances involved compared with the size of the model and the relatively light aerodynamic and heavy tare loading of the installation, sufficiently accurate readings of drag and moments cannot be obtained. For this reason, and to provide for the measurement of rolling moments, a second, body fixed balance system

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL2-0 INTRODUCTION - CONT'D.

is provided near the model.

This second balance employs ring type load gages to measure drag forces and pitching and rolling moments. Lift forces are also indicated on this balance, but since they include forces due to the model supply pressure, readings of lift will be taken on the tunnel balance only.

Aerodynamic loads on the model and support structure fairings are estimated using standard aerodynamic theory; the model lift, drag and moment coefficients being estimated from the results of previous tests. Hovering loads are based on Avro reports: AVRO/SPG/TR 29 & AVRO/SPG/TR 33. An ultimate load factor of 4 is used throughout.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL3-0 DESCRIPTION OF INSTALLATION -3-1 GENERAL -

Fig 1 shows the general arrangement of the installation. The model is suspended from a vertical arm below a horizontal tube attached to the main balance struts. The incidence of the model is adjusted by using the rear balance strut acting on a control arm extending from the horizontal tube.

In order to remove the airload from the model mounting, the whole installation is enclosed in a fairing supported independently of the balance system on the strut fairings.

Additional streamlining of the horizontal tube fairing is provided but has not been shown on fig 1 for clarity.

3-2 MODEL -

The model is composed of two dish-shaped steel turnings joined together to form a hollow circular wing; and three profiled turnings joined to form a circular center body (Fig 2).

The two halves of the wing are held apart by 24 radial ribs and attached together by screws into these ribs and into each other around the outer edge of the model. Each half contains three sets of holes distributed around three circles concentric with the model center as shown in fig 8. The holes are covered by segmented plates containing matching holes of a smaller diameter. Several sets of plates with different hole sizes are provided in order to vary the sizes of the final openings.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL-

3-0

DESCRIPTION OF INSTALLATION

3-2

MODEL - CONT'D.

The peripheral outlets are 336 holes: .242" dia. distributed along a circle of rad. 16.825". They are covered with segment plates having holes of dia. ranging in steps from .242" to .120" dia. Plates are also provided to close the holes completely.

The propulsive outlets are 48 holes: 1.40" dia. distributed along a circle of rad. 15.80". They are covered by the segment nozzle plates which direct the airflow aft at about 20° to the wing surface. Plates are also provided to close the holes completely.

Both of these outlets are covered by the same plates. Various arrangement of propulsion and control being provided by changing the plates.

The center outlets are 96 holes: .453" dia. distributed along a circle of rad. 11.312". They are covered with segment plates having holes of dia. ranging in steps from .453" to .228". Plates are also provided to close the holes completely.

The wing is clamped by bolts between two of the center body turnings. The upper turning (A in fig 2) is in the shape of a dummy intake and ramp and is attached to the outer model support tube. The center turning (B in fig 2) forms the lower intake ramp and connects with an inner tube to form a duct leading to the wing. High pressure air is admitted through this duct to exhaust through the openings described above to simulate the aircraft propulsive system.

The lower turning (C in fig 2) forms the lower intake roof and forms a duct leading to the center tube

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -3-0 DESCRIPTION OF INSTALLATION3-2 MODEL CONT'D.

This tube is partially evacuated to draw air through the intake to simulate lower intake airflow. The lower turning is attached to the center supply tube by a suspension rod and to center turning by six soldered tubes. These tubes also duct some of the high pressure air through a central nozzle in the lower turning to simulate the aircraft Viper exhausts.

This model is intended to simulate take-off, hovering and transition configurations close to a simulated ground board. For this reason, only the lower intake is used.

Hovering conditions will be tested for the model horizontal and tilted up to 20° .

Transition will be tested for angles of attack ranging from -10° to $+45^\circ$.

Ground distance will be adjusted from zero to about 2 dia.

3-3 MODEL SUPPORT STRUCTURE -

The model is attached at the end of a vertical arm (fig. 3) by a suspension rod and 4 ring gages measuring pitching and rolling moments and loads parallel to the model.

The vertical arm is made up of two concentric tubes which are connected to the model through elastic joints at the

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL3-0 DESCRIPTION OF INSTALLATION -3-3 MODEL SUPPORT STRUCTURE - CONT'D.

measuring gage section. The outside tube carries the pressure supply to the model while the inner tube carries the suction.

The lower part of the arm is removable together with the model and gage section by disconnecting a flange on the outside tube. The top & bottom of the inner tube in the removable section are connected to the upper part of the inner tube and to the model by sliding couplings so that all loads transmitted to the upper part of the arm are carried by the outer tube.

The model suspension rod is attached to the outer tube by means of a cruciform bracket at the level of the connecting flange. This bracket also supports the lower part of the inner tube.

The vertical arm is welded at its upper end to the horizontal tube and to the control arm.

The horizontal tube supplies pressure to the nozzles of the model on one side and suction to the intake of the model on the other side. It is supported at both ends by ball-bearing assemblies (fig 4). Bolted to the end of the main balance struts. It is attached to the external parts by means of bellows allowing free movement of the ends and is fixed against side motion at the pressure side ball-bearing. It is free to slide on the suction side to allow for thermal expansion. A tension rod takes the load due to pressure and suction in the tubes. This rod is attached at its outer end to a 3 armed bracket welded inside the horizontal tube coming through the tunnel wall on the pressure side.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL3-0 DESCRIPTION OF INSTALLATION3-3 MODEL SUPPORT STRUCTURE - CONT'D.

A similar bracket at the other end contains ball-bearings to avoid twisting of the rod when changing the angle of incidence of the model.

The control arm (fig. 5) is a welded steel structure in the shape of an I beam with height decreasing toward the rear balance strut.

3-4 FAIRINGS -

The vertical arm of the fairing (fig. 6) is a streamlined light alloy structure with wooden ribs and formers. The two lower parts of this fairing are removable to give access to the measuring gage section. It is attached at its upper end to the steel fairing of the control arm and to the horizontal tube fairing (fig 7)

The horizontal tube fairing is another steel tube concentric with the model support tube and supported at each end on plain bearings attached to the sides of boxes extending below the main balance strut fairings. In the section between tunnel wall and main balance strut, the fairing and the inner tube are assembled as a rigid unit. They are supported by the tunnel walls and the box extending below the main balance struts fairings.

The control arm fairing is a steel box and is attached by a linkage to the rear balance strut fairing.

All fairings are completely independant of

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the balance system and clearances are provided to ensure that no contact will occur through possible deflection of the structure or misalignments.

A follow-up mechanism maintains the alignment between the model support tubes and the fairings when changing the angle of attack of the model.

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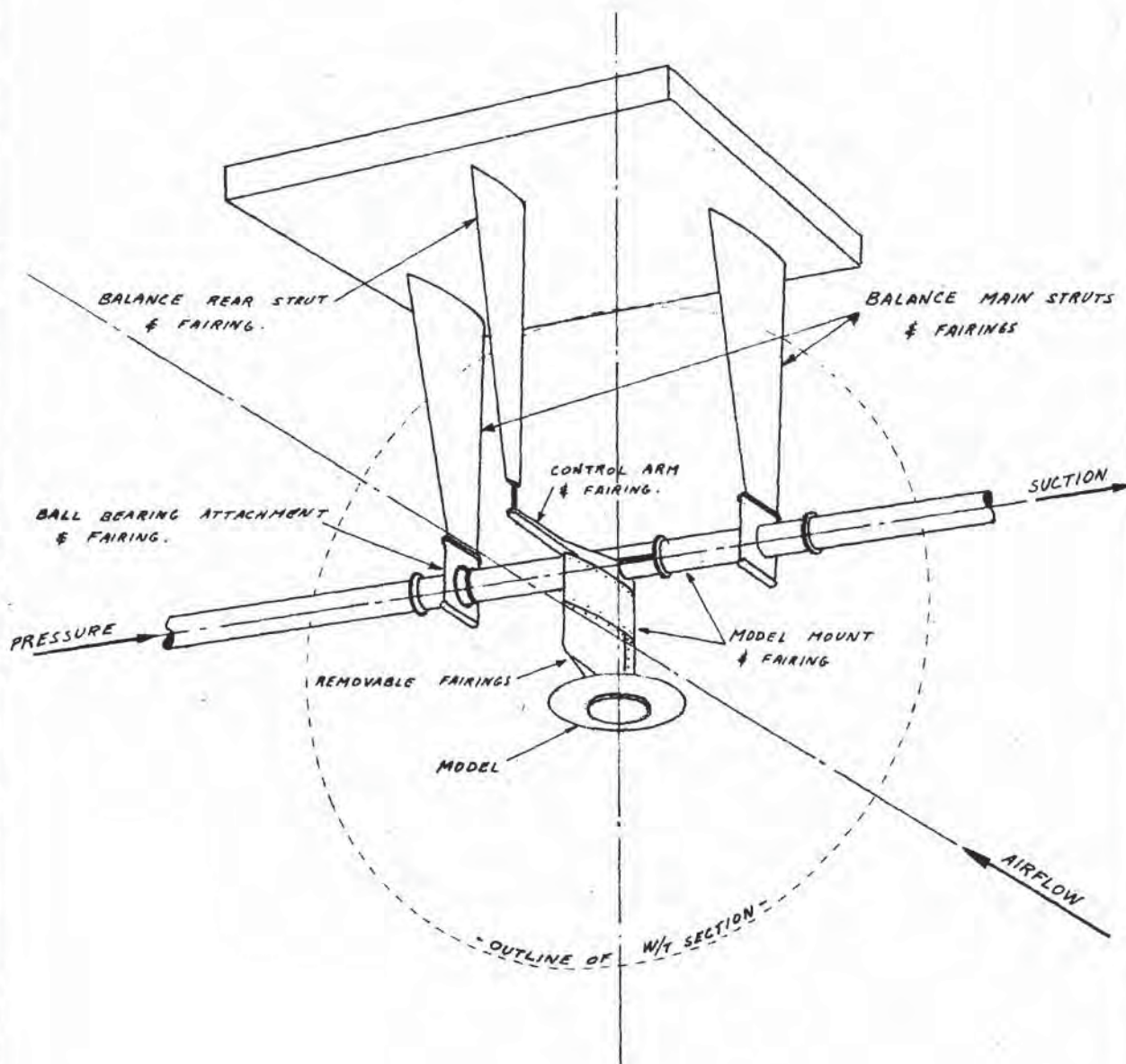
STRESS ANALYSIS OF $\frac{1}{2}$ SCALE HOVERING & TRANSITION MODEL

FIG 1 - GENERAL ARRANGEMENT OF INSTALLATION

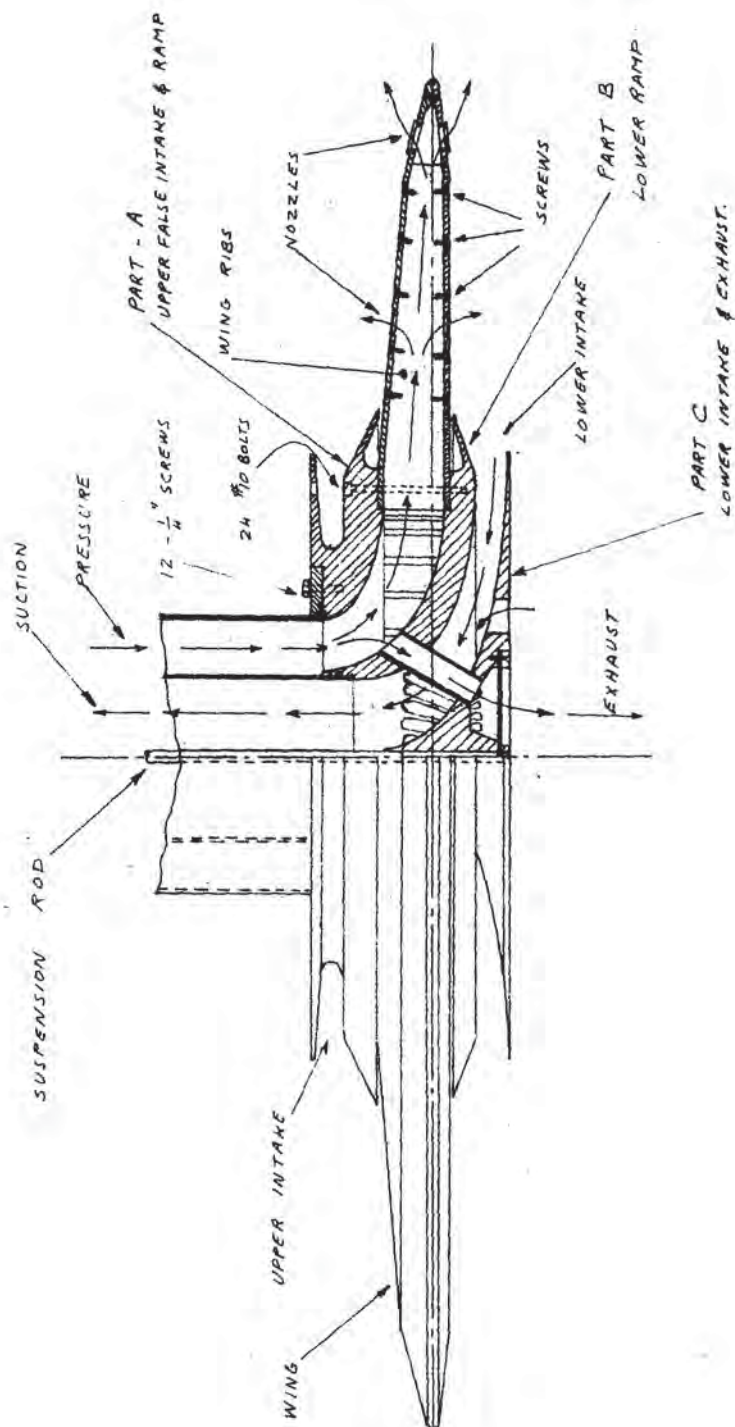
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELFIG-2 - $\frac{1}{12}$ SCALE HOVERING AND TRANSITION MODEL

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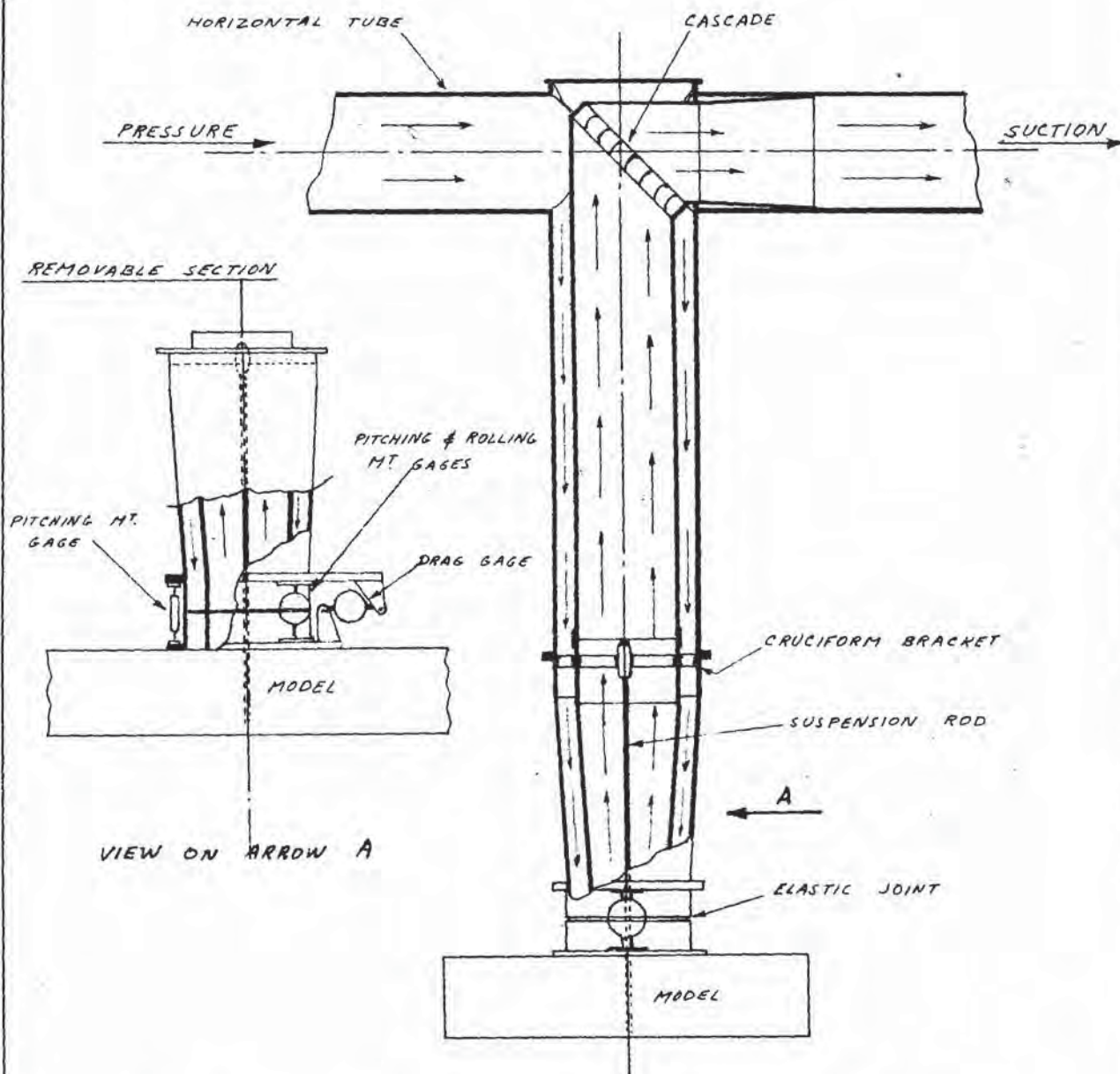
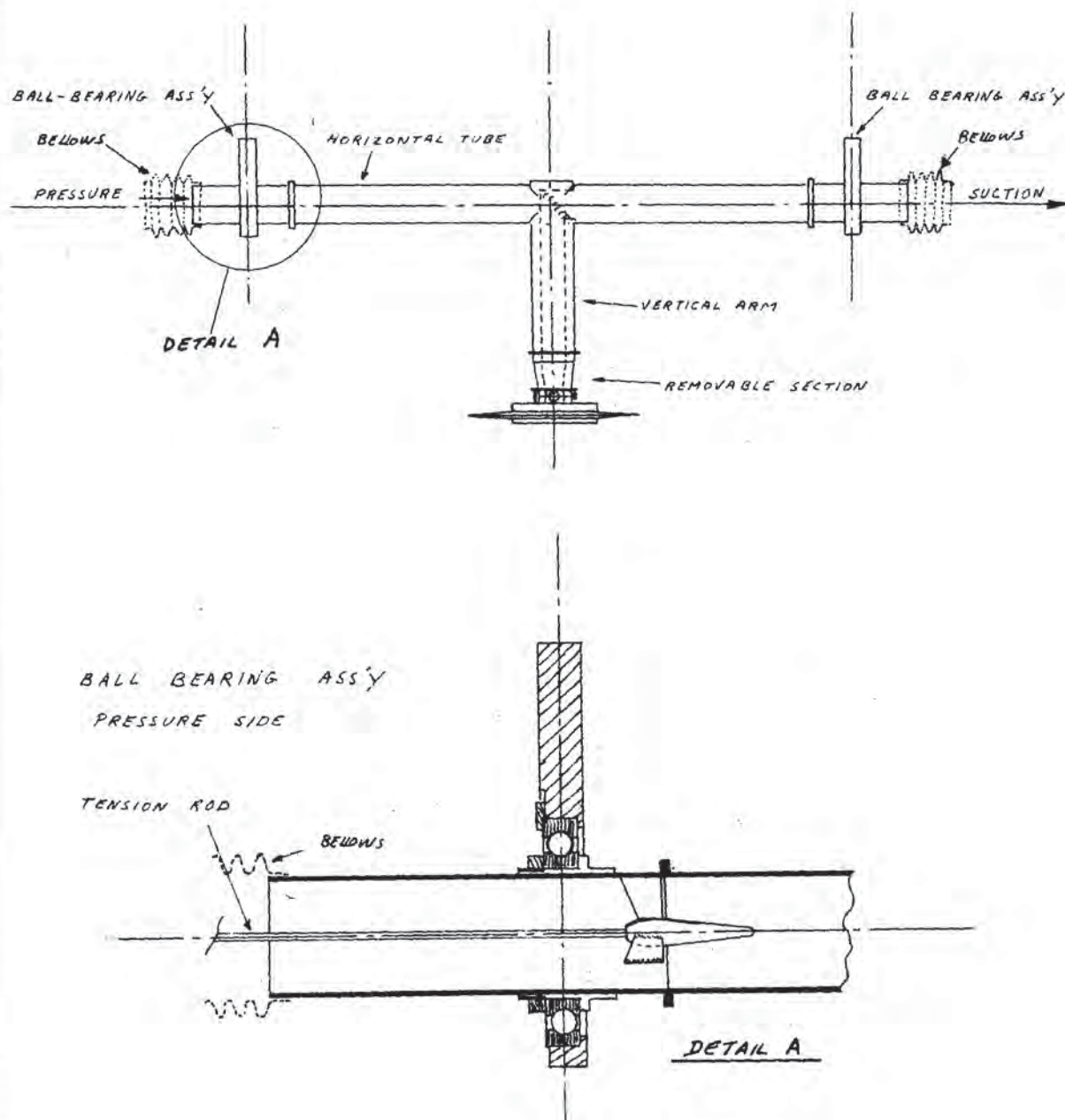
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FIG-3 - DETAILS OF MODEL SUPPORT - A

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELFIG-4 - DETAILS OF MODEL SUPPORT - B

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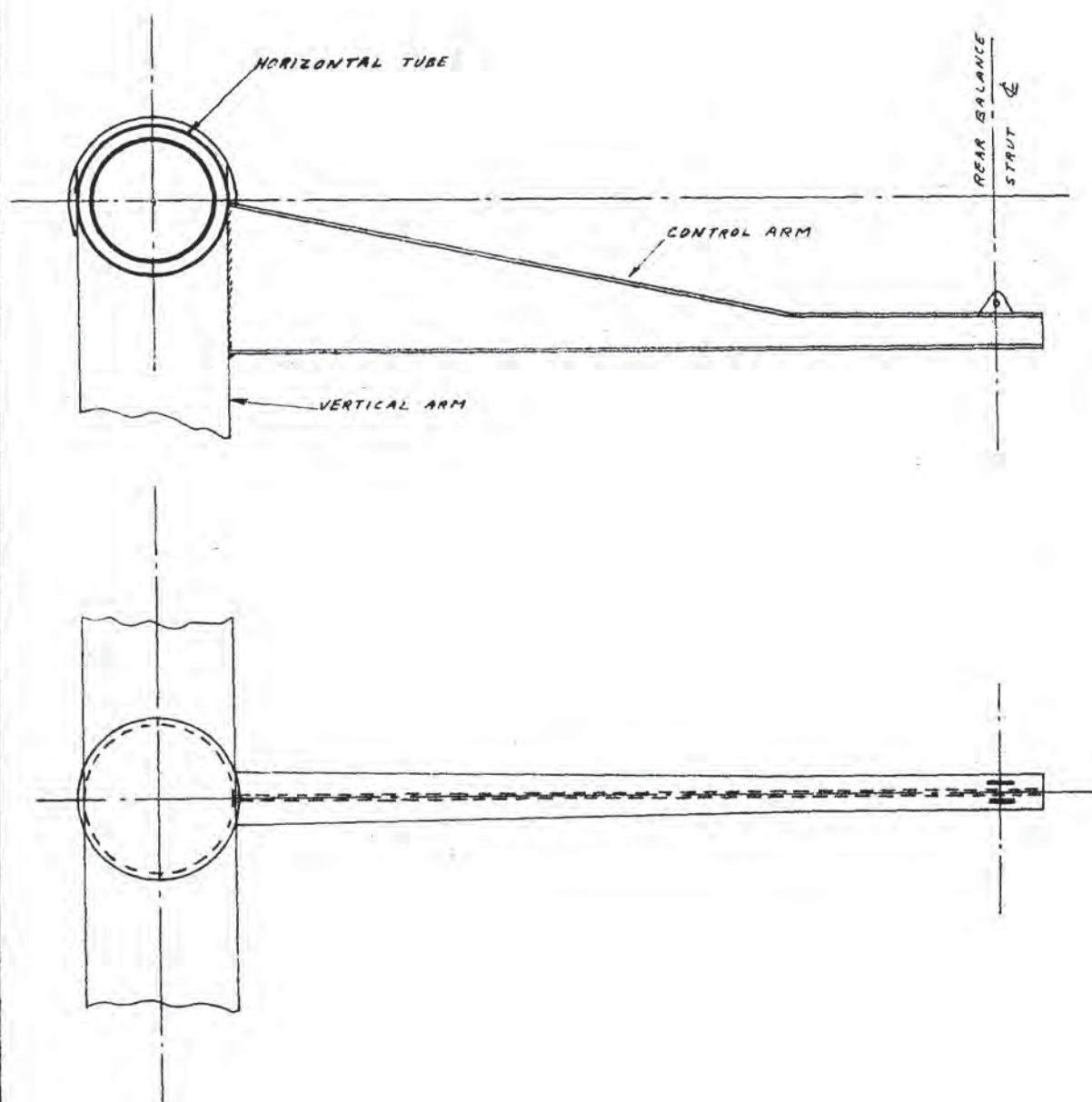
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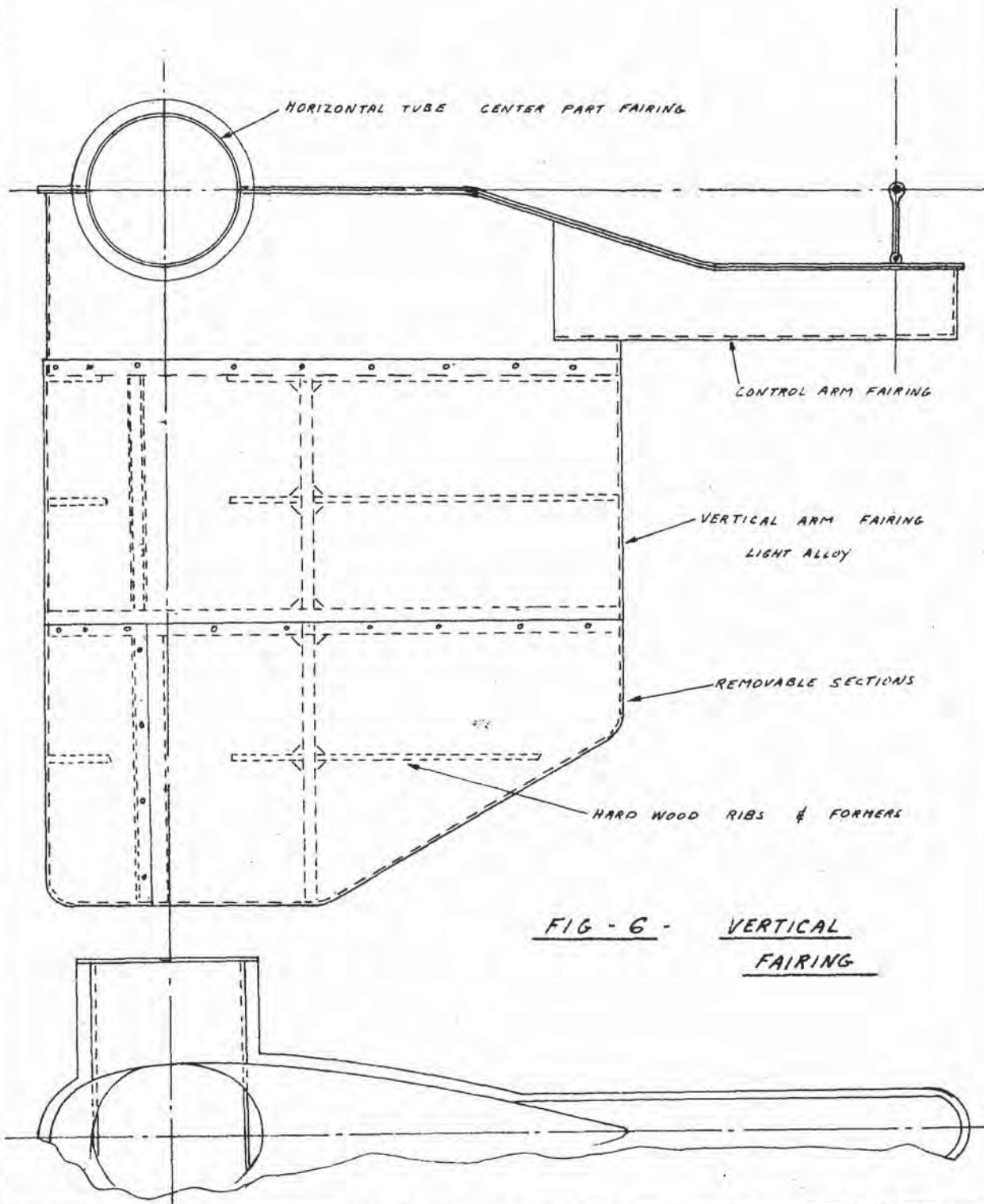
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELFIG. 5 - CONTROL ARM

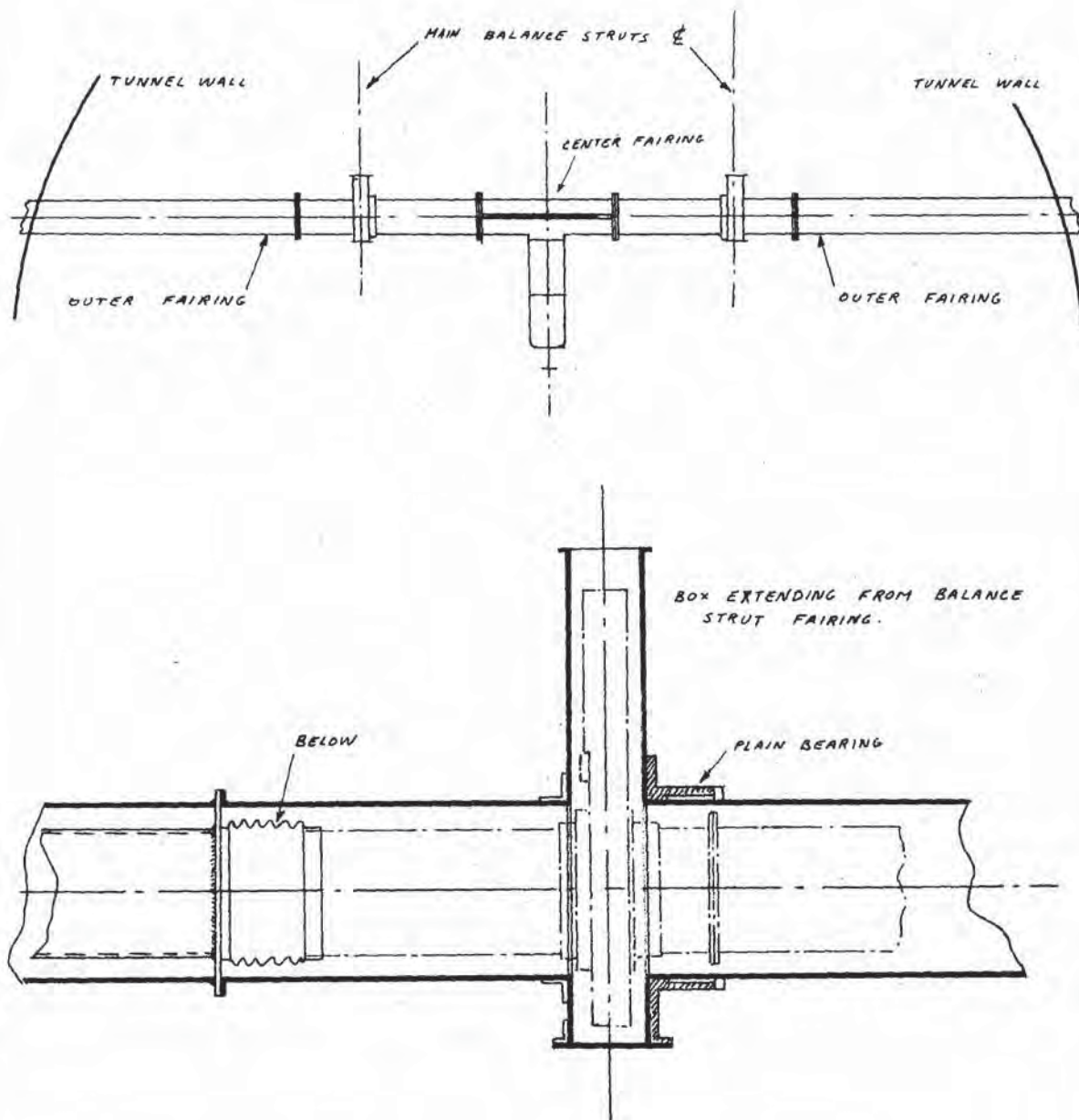
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- STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -4-0LOAD ANALYSIS4-1LOADING CONSIDERATIONS-4-1.1. General.

The model forces are taken by the ring load measuring gages and transferred through the model support to the 3 balance struts.

The fairing loads, both static and aerodynamic are taken by the 3 balance strut fairings.

4.1.2 Loads on the model

The model loads include: weight, aerodynamic loads, jet reaction and pressure forces on the ducting.

jet reaction: In the hovering cases, the jet reaction is entirely directed downward. In the flying cases, the jet reaction may be divided between lifting and propelling thrust. In all cases, it must be assumed that the jets will be operating with the tunnel stopped, thus the loads will not be relieved by air drag or lift. Pressure and suction on the ducting area at the inlet of the model will add a force normal to the plane of the model. These pressures and suctions will be assumed uniform over the area thus having no moment about the center of the model. It should be noted that this may not be true in practice. However, since the moment is likely to be relatively small and owing to difficulties in obtaining reliable estimates, this moment has been neglected in the analysis. Also, the full delivery pressure and suction have been used while some drop is to be expected.

Aerodynamic loading The model can be placed in the tunnel at angles α varying between -10° & 45° with a preferential range from -10° to 20° . The tunnel is to

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -4-0 LOAD ANALYSIS.4-1 LOADING CONSIDERATIONS - CONT'D.

be operated at $q = 30$ PSF for the preferential range and its speed will be reduced for the range 20° to 45° so that the airloads do not exceed those produced in the preferential range thus allowing the use of smaller ring load measuring gages at the model attachment.

Since accurate values of C_L , C_D & C_m are not available, these parameters have been taken on the high side in order to ensure that the stressing of the model will amply cover all possible cases.

4.1.3 Model supporting structure. The model supporting structure takes the model loading plus the static loads due to its own weight and pressure loads in the ducting.

4.1.4 Fairings. The fairing loading is both static and aerodynamic: i.e. fairing weight and air drag. In addition, it has been assumed that a deviation of the airflow in the tunnel would not induce more than a 5° angle of attack to the vertical fairing hence producing a side load on the attachment of the fairing.

4.1.5 Load Factor:

A load factor $n = 4$ is applied to all parts of the structure except on the ring load measuring gages which are stressed for their operating conditions as per report AVRO/SPG/TR 87.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-0 LOAD ANALYSIS-4-2 MODEL LOADS4-2-1 LOADING CASES

HOVERING CASES

| α | T | q _{PSF} | LIFT $E_L = \frac{L}{T}$ | MOMENT $E_M = \frac{M}{Tb}$ | SIDE LOAD $E_S = \frac{S}{T}$ |
|----------|------|------------------|-----------------------------|--------------------------------|----------------------------------|
| 0° | FULL | 0 | 2.0 | 0 | 0 |
| 20° | FULL | 0 | 2.0 | .15 | .30 |

Ref: AVRO/SPG/TR 29 & AVRO/SPG/TR 33

TRANSITION CASES

| α | T | P | q _{PSF} | C_L | C_D | $C_{m \frac{1}{2}}$ |
|----------|------|------|------------------|-------|-------|---------------------|
| -10° | 0 | FULL | 30 | -.30 | .08 | -.60 |
| 0° | 0 | 0 | 30 | .05 | .05 | -.20 |
| 0° | FULL | FULL | 0 | | | |
| 20° | 0 | FULL | 30 | 2.1 | .60 | .18 |
| 35° | 0 | FULL | 30 | 2.8 | 1.20 | .32 |
| 45° | 0 | FULL | 18 | 3.0 | 1.70 | * .98 |

* As determined from assumed distribution.

Values of C_L , C_D & $C_{m \frac{1}{2}}$ are based on estimates from previous testingSYMBOLS.

T: THRUST.

P: SUPPLY PRESSURE

q: TUNNEL DYNAMIC PRESSURE

 E_L , E_M , E_S : THRUST EFFICIENCIES IN HOVERING CASES C_L , C_D , $C_{m \frac{1}{2}}$: AERODYNAMIC COEF.

NOTE. TRANSITION CASES WERE SELECTED FOR MOST ADVERSE LOADS ON
THE GAGES RATHER THAN ACTUAL TEST CASES.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.4-0 LOAD ANALYSIS4-2-1 LOADING CASESLOADS DUE TO INTERNAL PRESSURE:

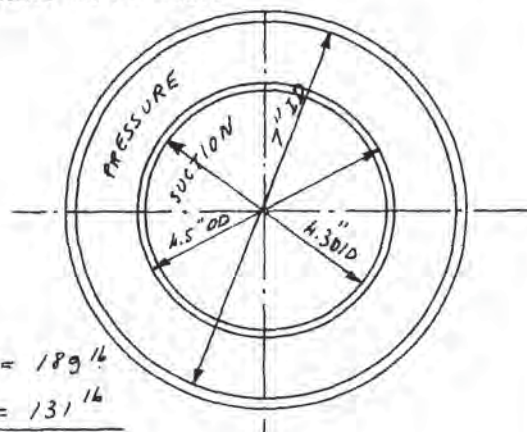
- max. model pressure: 30.7A PSI. (simulated hot thrust with hot nozzle area)
- max. operating pressure*: 22.96 PSIA in jet flow circuit
4.98 PSIA in intake flow circuit

*. based on: - simulated hot thrust with cold nozzle area

- pressure loss in jet flow circuit = 5 x dynamic head based on ave. internal flow area and nozzle total head.
- pressure loss in intake flow circuit = 1.5 x dynamic head based on intake flow area and intake total head.

$$\text{SUCTION AREA: } \frac{\pi}{4} 4.3^2 = 14.5 \text{ in}^2$$

$$\text{PRESSURE AREA: } \frac{\pi}{4} (7^2 - 4.5^2) = 22.6 \text{ in}^2$$

LOADS DUE TO PRESSURE.

$$\text{Force due to static pressure: } (22.96 - 14.7) 22.5 = 189 \text{ lb}$$

$$\begin{array}{r} \text{Force due to momentum flow:} \\ \text{net force} \end{array} \quad \begin{array}{r} = 131 \text{ lb} \\ \hline 320 \text{ lb} \end{array}$$

LOADS DUE TO SUCTION

$$\text{Force due to static pressure: } (4.98 - 14.7) 14.5 = -138 \text{ lb}$$

$$\begin{array}{r} \text{Force due to momentum flow:} \\ \text{net force:} \end{array} \quad \begin{array}{r} = 104 \text{ lb} \\ \hline - 34 \text{ lb} \end{array}$$

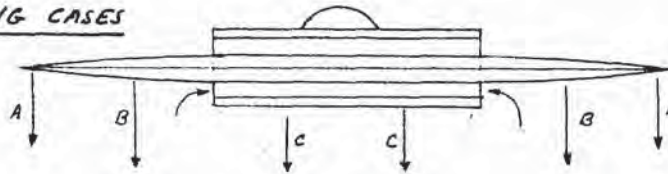
$$\text{net load on model: } 320 - 34 = 286 \text{ lb}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4.0. LOAD ANALYSIS4-2-2. HOVERING CASESHORIZONTAL

Lift provided by A or B or A+B: 150 lb

Lift provided by C: 11 lb

Ground efficiency: $\frac{L}{T} = 2.0$

Total lift on the model: $2.0 \times (150 + 11) = \underline{\underline{322 \text{ lb}}}$

- In the absence of more accurate data, $\frac{1}{2}$ of this load will be taken as concentrated at the jets, the other $\frac{1}{2}$ as a uniform pressure on the undersurface:

Wing area: $35.33 \frac{\pi}{4} = 978 \text{ in}^2$

Pressure: $\frac{161}{978} = .165 \text{ PSI}$

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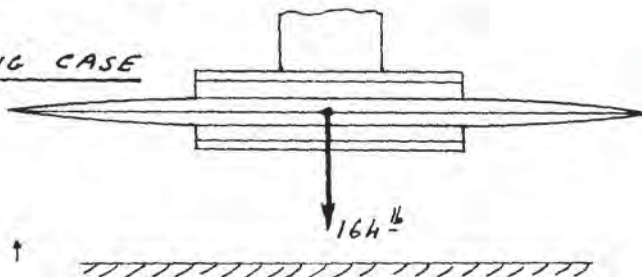
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-0 LOAD ANALYSIS4-2-2 HOVERING CASEHORIZONTAL
NET LOADS

LIFT : 322 lb ↑
 WEIGHT : 200 lb ↓
 PRESS : 286 lb ↓

$$\text{NET LOAD : } 200 + 286 - 322 = 164 \text{ lb} \downarrow$$

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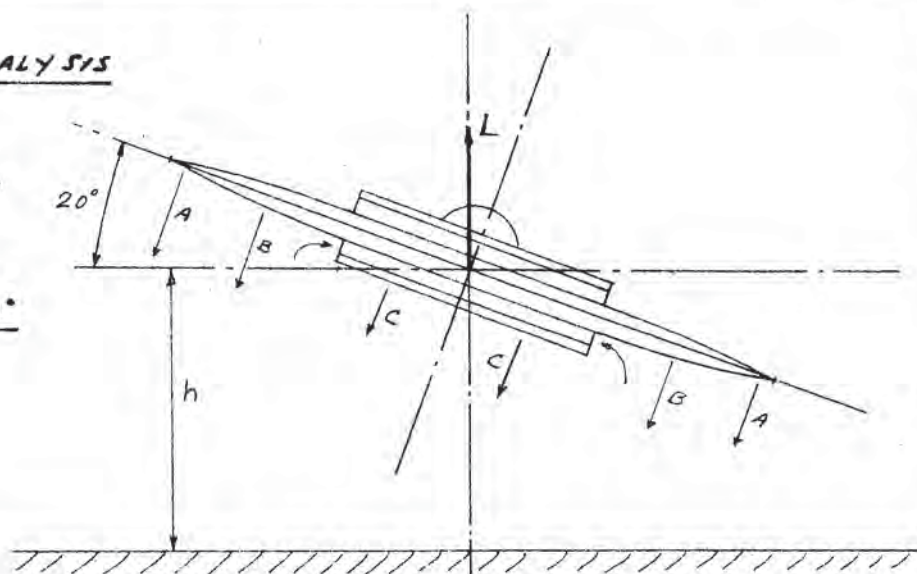
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELH-0 LOAD ANALYSISH-2.2 - HOVERING CASEHOVERING AT 20° AIR LOADS

Efficiencies:

LIFT on GROUND. $E_L = \frac{L}{T} = 2.0$

$\therefore L = 2T$

MOMENT $E_M = \frac{M}{Tb} = .15$

$\therefore M = .15 Tb$

SIDE LOAD $E_S = \frac{S}{T} = .30$

$\therefore S = .30 T$

Ref:
AVRO/SPG/TR 23
AVRO/SPG/TR 33

Lift provided by A or B or A+B : 150 lb
Lift provided by C : 11 lb } 161 lb

Total lift on the model: $2 \times 161 = \underline{322 \text{ lb}}$ normal to the floor.In the absence of more accurate data lift distribution will be taken as for hovering case at $\alpha = 0^\circ$.

Moment : $.15 \times 161 \times 35.3 = \underline{853 \text{ in. lb}}$

Side load : $.30 \times 161 = \underline{48.3 \text{ lb}}$ in any direction in the plane of the floor.

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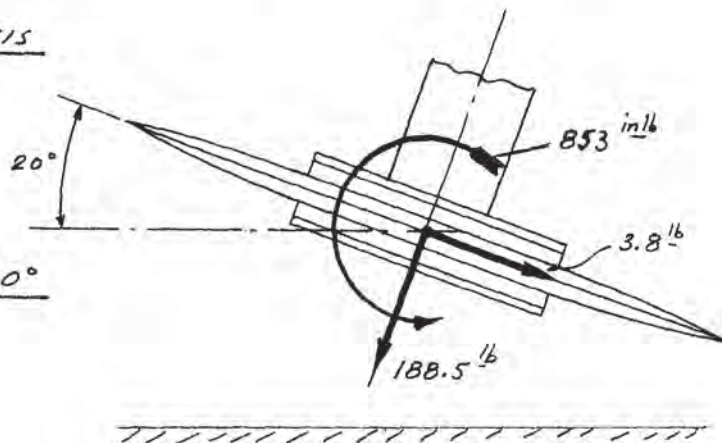
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-0 LOAD ANALYSIS4-2-2. HOVERING CASEHOVERING AT 20°
NET LOADSLIFT: 322 lb normal to the floor. ↑SIDE LOAD: 48.3 lb in any direction. Here taken as shown →MOMENT: 853 in/lb ↺WEIGHT: 200 lb normal to the floor ↓PRESSURE: 286 lb normal to the model ↓

Total force normal to the model:

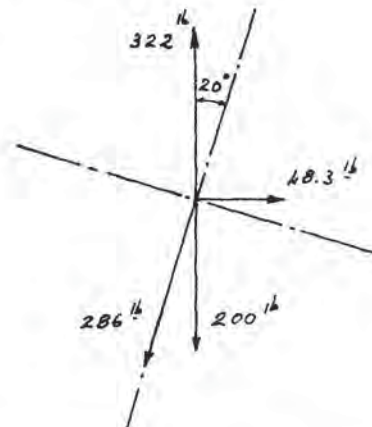
$$286 + 200 \cos 20^\circ - 322 \cos 20^\circ + 48.3 \sin 20^\circ =$$

$$286 + 188 - 302 + 16.5 = 188.5 \text{ lb} \downarrow$$

Total force parallel to the model:

$$200 \sin 20^\circ - 322 \sin 20^\circ + 48.3 \cos 20^\circ =$$

$$68.4 - 110 + 45.4 = 3.8 \text{ lb} \rightarrow$$



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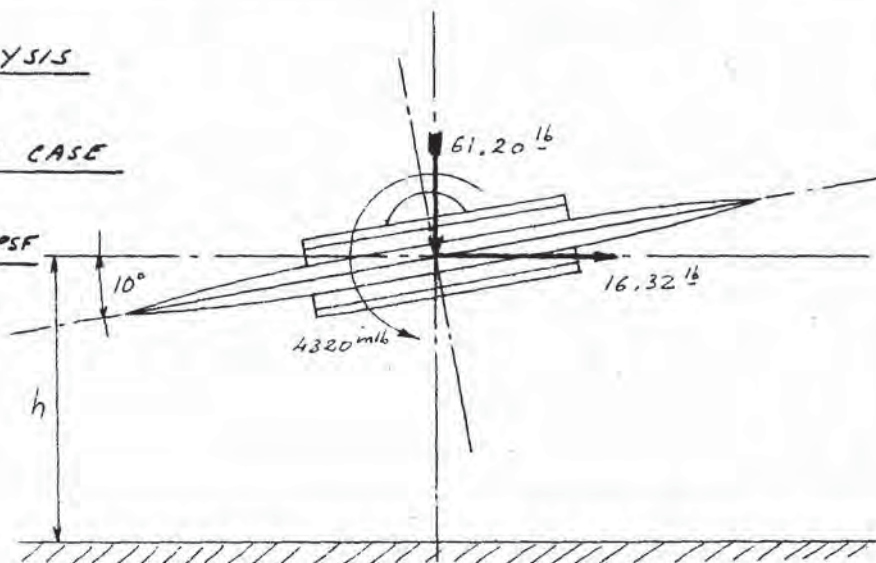
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-0 LOAD ANALYSIS4-2.3 TRANSITION CASE-10° CASE - $q = 30$ PSFAIR LOADS

$C_L = -.30$

$C_D = .08$

$C_M = -.60$

Tunnel q : 30 PSFWing area : 6.8 ft²

Wing chord : 2.94 ft

LIFT : $-.30 \times 6.8 \times 30 = -61.20 \text{ lb}$

DRAG : $.08 \times 6.8 \times 30 = 16.32 \text{ lb}$

MOMENT : $-.60 \times 2.94 \times 6.8 \times 30 = -360 \text{ ft-lb} = -4320 \text{ in-lb}$

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G. Jacquemont

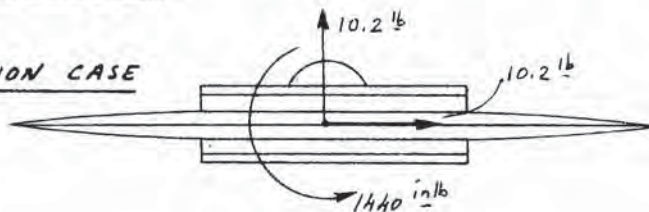
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-0 LOAD ANALYSIS4-2-3 TRANSITION CASE

ZERO THRUST: $\alpha = 0$
AIR LOADS

$$C_L = .05$$

$$C_D = .05$$

$$C_{M_{cg}} = -.20$$

$$\text{Tunnel } q = 30 \text{ PSF.}$$

$$\text{Wing area } 6.8 \text{ ft}^2$$

$$\text{LIFT: } .05 \times 6.8 \times 30 = 10.2 \text{ lb}$$

$$\text{DRAG: } .05 \times 6.8 \times 30 = 10.2 \text{ lb}$$

$$\text{MOMENT: } 2.94 \times -.20 \times 6.8 \times 30 = -120 \text{ ft lb} = -1440 \text{ in lb}$$

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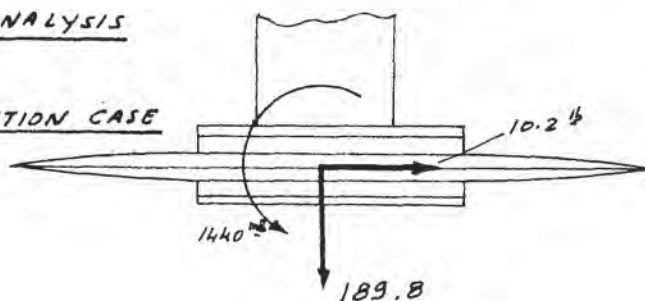
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-0 - LOAD ANALYSIS4-2-3 TRANSITION CASEZERO THRUST: $\alpha = 0$ NET LOADS

LIFT: $10.2^{lb} \uparrow$
 DRAG: $10.2^{lb} \rightarrow$
 MOMENT: $1440^{in lb} \curvearrowleft$
 WEIGHT: $200^{lb} \downarrow$

TOTAL FORCE NORMAL TO MODEL:

$$+ 200 - 10.2 = 189.8^{lb}$$

TOTAL FORCE PARALLEL TO MODEL:

$$10.2^{lb}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-0 LOAD ANALYSIS4-2-3 TRANSITION
CASEMAX. THRUST CASE.

$\alpha = 0$

$T = 141.16$

$\alpha = 0$

$V = 0$

Thrust: $150 \cos 20^\circ = 141.16$

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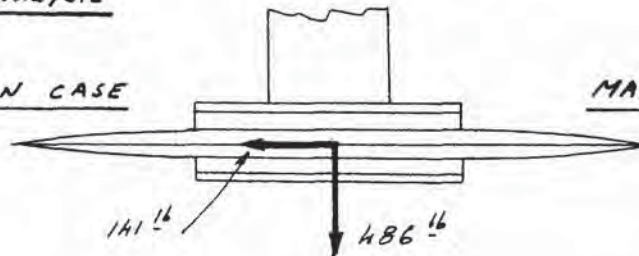
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-0 LOAD ANALYSIS4-2-3 TRANSITION CASE

MAX THRUST CASE $\alpha = 0$
NET LOADS

THRUST : 141 $\frac{lb}{lb}$ ←

WEIGHT : 200 $\frac{lb}{lb}$ ↓

PRESSURE : 286 $\frac{lb}{lb}$ ↓

TOTAL FORCE NORMAL TO MODEL.

$$200 + 286 = 486 \frac{lb}{lb} \downarrow$$

TOTAL FORCE PARALLEL TO MODEL

$$141 \frac{lb}{lb} \leftarrow$$

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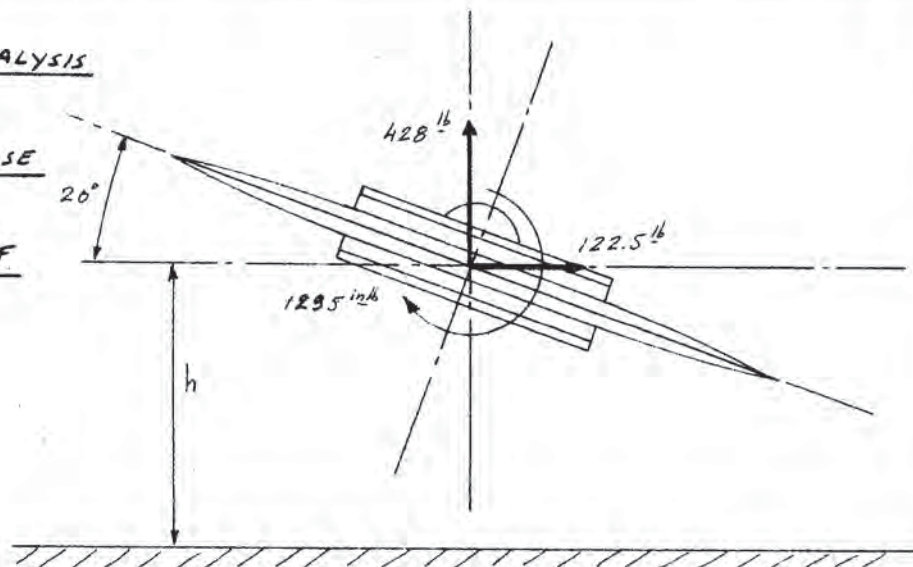
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4.0 - LOAD ANALYSIS4.2.3 TRANSITION CASE

20° CASE - $q = 30$ PSF
AIRLOADS

$$C_L : 2.1$$

$$C_D : .60$$

$$C_{M_{\frac{c}{2}}} : .18$$



Tunnel q : 30 PSF

Wing area : 6.8 ft²

Wing chord : 2.94 ft

$$\text{LIFT} : 2.1 \times 6.8 \times 30 = 428 \text{ lb}$$

$$\text{DRAG} : .60 \times 6.8 \times 30 = 122.5 \text{ lb}$$

$$\text{MOMENT} : .18 \times 6.8 \times 30 \times 2.94 = 108 \text{ ft lb} = 1295 \text{ in lb}$$

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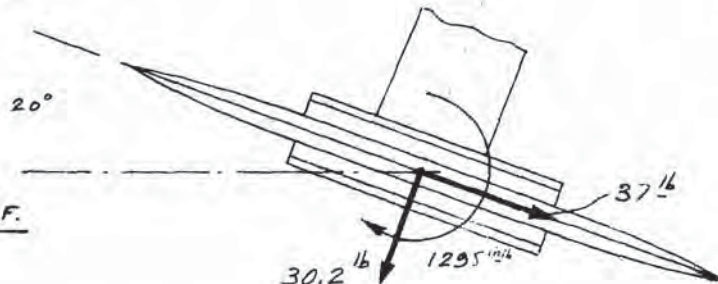
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-0 LOAD ANALYSIS4-2-3 TRANSITION
CASE20° CASE - $q = 30$ PSF.

NET LOADS



LIFT : 428 $\frac{lb}{\uparrow}$
 DRAG : 122.5 $\frac{lb}{\rightarrow}$
 MOMENT : 129.5 $\frac{in-lb}{\curvearrowright}$
 WEIGHT : 200 $\frac{lb}{\downarrow}$
 PRESSURE : 286 $\frac{lb}{\downarrow}$

TOTAL FORCE NORMAL TO THE MODEL:

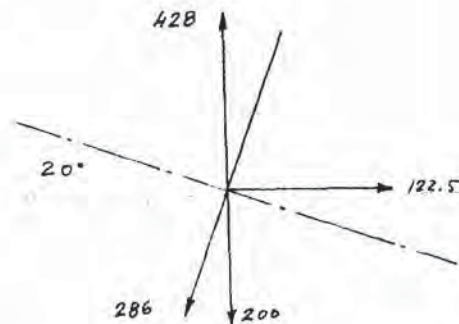
$$286 + 200 \cos 20^\circ - 428 \cos 20^\circ - 122.5 \sin 20^\circ =$$

$$286 + 188 - 402 - 41.8 = 30.2 \frac{lb}{\downarrow}$$

TOTAL FORCE PARALLEL TO THE MODEL

$$200 \sin 20^\circ - 428 \sin 20^\circ + 122.5 \cos 20^\circ =$$

$$68.4 - 146.4 + 115 = 37 \frac{lb}{\rightarrow}$$



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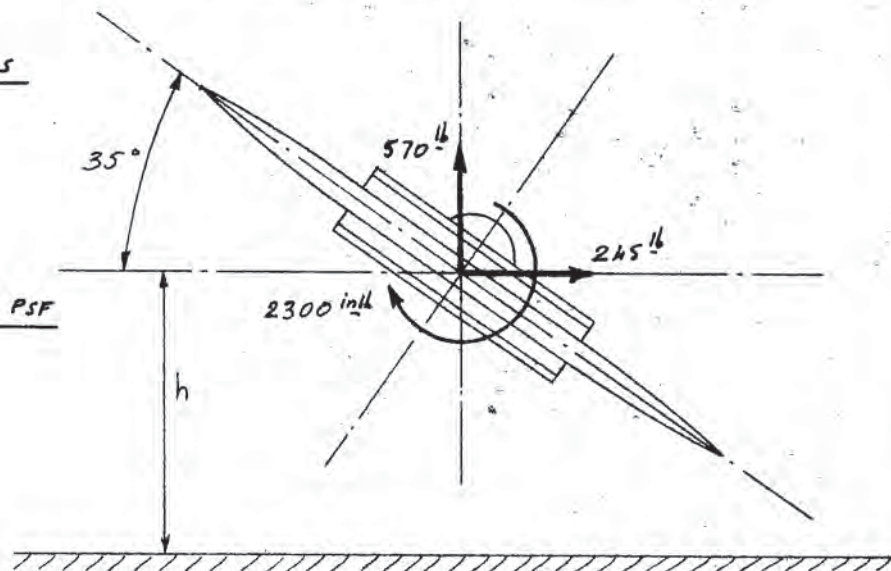
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-0. LOAD ANALYSIS4-2.3 - TRANSITION
CASE35° CASE - $q = 30$ PSFAIRLOADS $C_L : 2.8$ $C_D : 1.20$ $C_{M_{\frac{c}{2}}} : .32$ Tunnel $q : 30$ PSFWing area : 6.8 ft^2 Wing chord : 2.94 ft LIFT: $2.8 \times 6.8 \times 30 = 570 \text{ lb}$ DRAG: $1.20 \times 6.8 \times 30 = 245 \text{ lb}$ MOMENT: $.32 \times 6.8 \times 30 \times 2.94 = 192 \text{ ftlb} = 2300 \text{ inlb}$ WRITTEN BY

G. Jacques

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P. J. Jacques

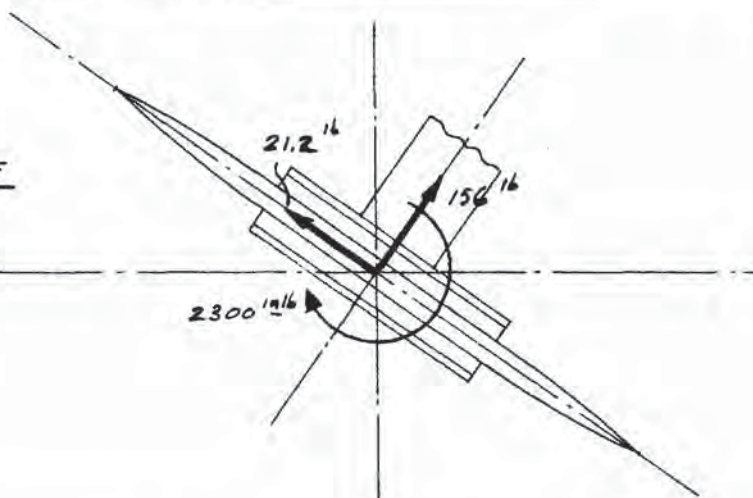
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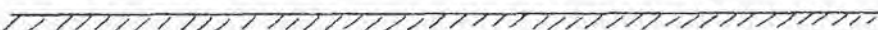
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -4-0 LOAD ANALYSIS4-2-3 TRANSITION CASE35° CASE - $q = 30$ PSF.NET LOADS

LIFT : 570 ^{lb} ↑
 DRAG : 245 ^{lb} →
 MOMENT: 2300 ^{in lb} ↻
 WEIGHT : 200 ^{lb} ↓
 PRESSURE: 286 ^{lb} ↙



TOTAL FORCE NORMAL TO THE MODEL:

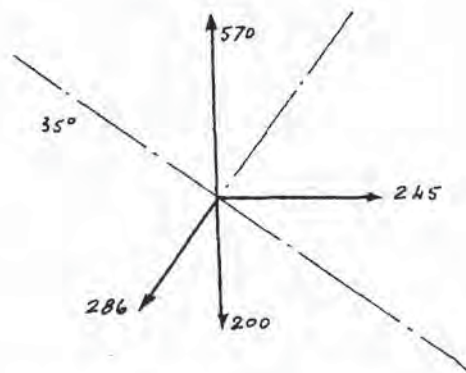
$$286 + 200 \cos 35^\circ - 570 \cos 35^\circ - 245 \sin 35^\circ =$$

$$286 + 164 - 466 - 140 = -156 \text{ } ^{\text{lb}} \uparrow$$

TOTAL FORCE PARALLEL TO THE MODEL

$$200 \sin 35^\circ - 570 \sin 35^\circ + 245 \cos 35^\circ =$$

$$104.8 - 327 + 201 = -21.2 \text{ } ^{\text{lb}} \leftarrow$$



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELH-0 LOAD ANALYSISH-2.3 TRANSITION CASE45° CASE - $q = 30$ PSFAIRLOADS

$$C_L = 3.0$$

$$C_D = 1.7$$

Wing area: 6.8 ft^2 TUNNEL AT $30 \text{ } q$

LIFT.

$$3.0 \times 6.8 \times 30 = \underline{\underline{612 \text{ lb}}}$$

DRAG.

$$1.7 \times 6.8 \times 30 = \underline{\underline{347 \text{ lb}}}$$

Assuming pres. distribution as shown
: Center of Pressure:

$$X = \frac{M}{V}$$

Volume element:

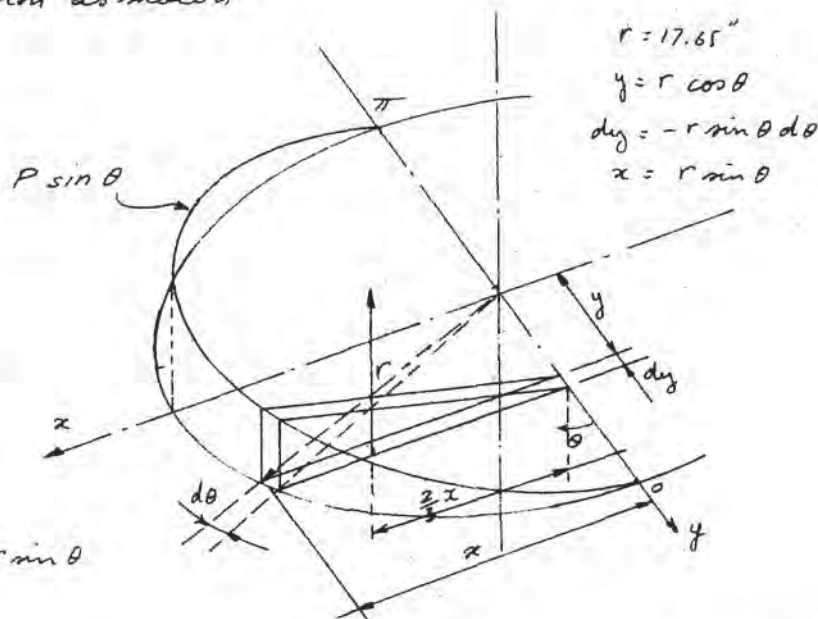
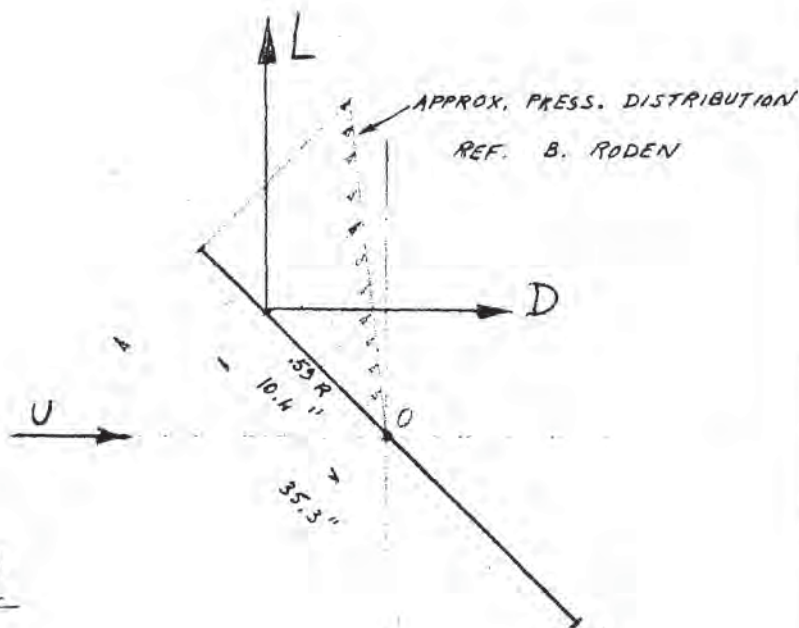
$$dV = \frac{1}{2} x dy P \sin \theta$$

$$dV = -\frac{P}{2} r^2 \sin^3 \theta d\theta$$

$$\therefore V = \int_{\pi}^0 -\frac{P}{2} r^2 \sin^3 \theta d\theta$$

$$dM = -\frac{P}{2} r^2 \sin^3 \theta d\theta \frac{2}{3} r \sin \theta$$

$$dM = -\frac{P}{3} r^3 \sin^4 \theta d\theta$$



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

$$M = \int_{\pi}^0 -\frac{P}{3} r^3 \sin^4 \theta d\theta \quad \text{LOAD ANALYSIS}$$

$$\therefore X = \frac{-\int_{\pi}^0 \frac{P}{3} r^3 \sin^4 \theta d\theta}{-\int_{\pi}^0 \frac{P}{2} r^2 \sin^3 \theta d\theta} = \frac{\frac{2}{3} r \int_{\pi}^0 \sin^4 \theta d\theta}{\int_{\pi}^0 \sin^3 \theta d\theta} = \frac{3}{16} \pi r = .59 r.$$

$$V = \frac{2}{3} P r^2 \quad \text{where } V \text{ is component normal to the disc.}$$

$$\therefore X = .59 \frac{35.3}{2} = 10.4''$$

Moment of lift & drag about center of model:

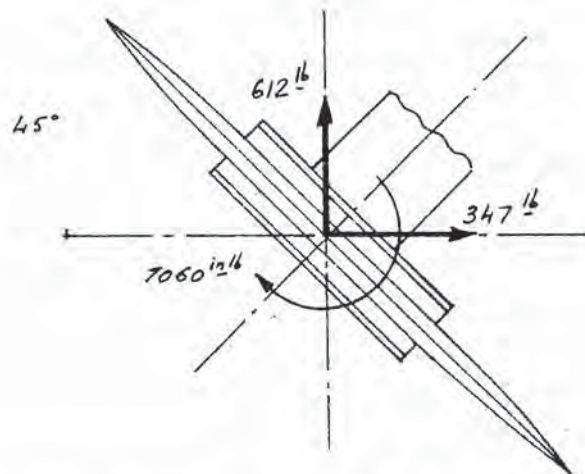
$$(612 + 347) \frac{10.4}{\sqrt{2}} = \underline{\underline{7060 \text{ in}^2 \text{ lb}}}$$

Component normal to surface of disc:

$$V = (612 + 347) \frac{1}{\sqrt{2}} = 678 \text{ lb} \quad \therefore P = \frac{3}{2} 678 \times \left(\frac{35.3}{2}\right)^2 = 5.26 \frac{\text{lb}}{\text{in}^2}$$

Component in the plane of the disc:

$$(612 - 347) \frac{1}{\sqrt{2}} = 187.5 \text{ lb}$$



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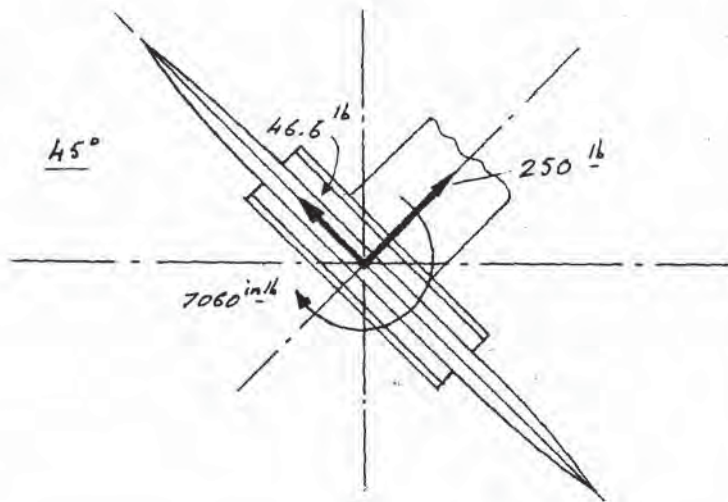
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELH-O LOAD ANALYSIS4-2-3 TRANSITION CASE45° CASE - $q = 30$ PSF.NET LOADS

LIFT: 612 lb ↑

DRAG: 347 lb →

MOMENT: 7060 in/lb ↺

WEIGHT: 200 lb ↓

PRESSURE: 286 lb ↓

TOTAL FORCE NORMAL TO THE MODEL:

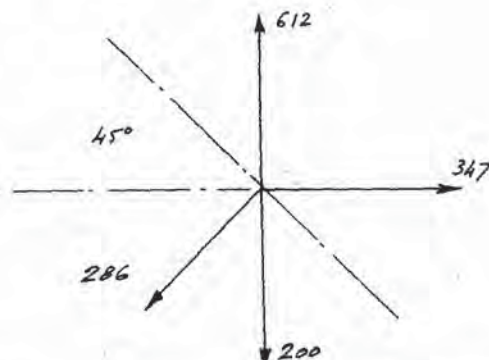
$$286 - 612 \cos 45^\circ + 200 \cos 45^\circ - 347 \sin 45^\circ =$$

$$286 - 433 + 141.4 - 245 = -250 \text{ lb} \quad \checkmark$$

TOTAL FORCE PARALLEL TO THE MODEL

$$200 \sin 45^\circ - 612 \sin 45^\circ + 347 \cos 45^\circ =$$

$$141.4 - 433 + 245 = -46.6 \text{ lb} \quad \checkmark$$



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -4-0 LOAD ANALYSIS4-2-3 TRANSITION CASE45° CASE - $q = 30$ PSF.Determination of $C_{M \frac{c}{2}}$ at $\alpha = 45^\circ$.

The moment about the center of the model is : 7060 $\frac{\text{in}}{\text{lb}}$
 This moment is due to aerodynamic forces alone. Hence the value of $C_{M \frac{c}{2}}$ is:

$$C_{M \frac{c}{2}} = \frac{M}{CSq} = \frac{\frac{7060}{12}}{\frac{35.3}{12} \times 6.8 \times 30} = \frac{7060}{7200} = +.98$$

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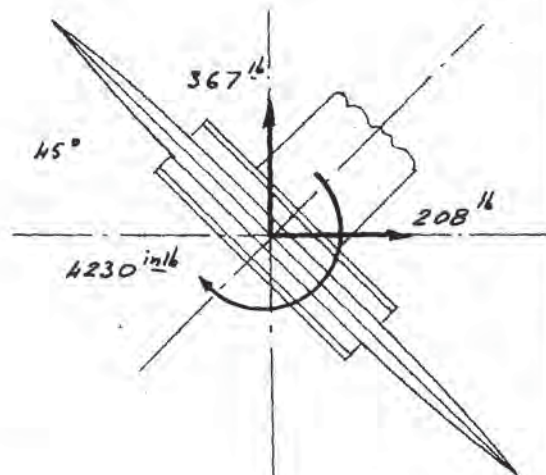
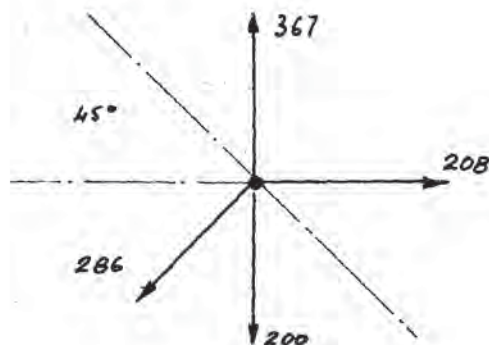
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL-4.0 LOAD ANALYSIS4-2-3 TRANSITION CASE-CASE 45° TUNNEL OPERATING AT 18 g.

$$\text{Lift: } 612 \times \frac{18}{30} = 367 \text{ lb}$$

$$\text{Drag: } 347 \times \frac{18}{30} = 208 \text{ lb}$$

$$\text{Moment: } 7060 \times \frac{18}{30} = 4230 \text{ in lb}$$



FORCE NORMAL TO THE MODEL:

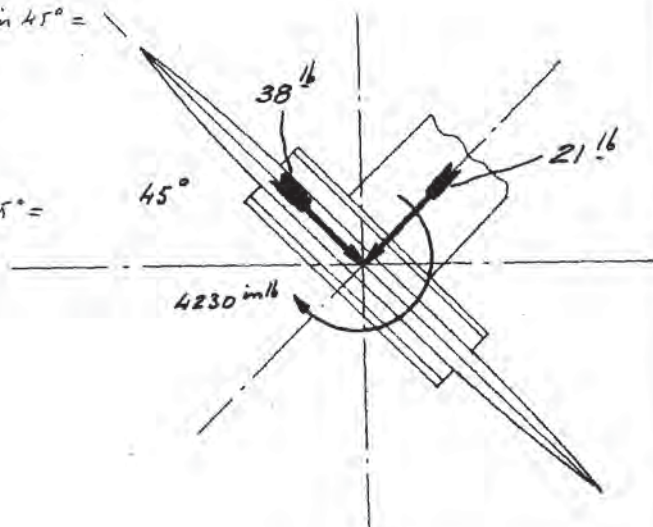
$$286 + 200 \cos 45^\circ - 367 \cos 45^\circ - 208 \sin 45^\circ =$$

$$286 + 141 - 259 - 147 = +21 \text{ lb}$$

FORCE PARALLEL TO THE MODEL:

$$200 \sin 45^\circ + 208 \sin 45^\circ - 367 \sin 45^\circ =$$

$$141 + 147 - 259 = 38 \text{ lb}$$



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELA-0LOAD ANALYSISA-2-4SUMMARY OF CRITICAL LOADING CASES -

The critical case is the transition case for $\alpha = -10^\circ$ which give together the max. pitching moment and the max. downward load normal to the model

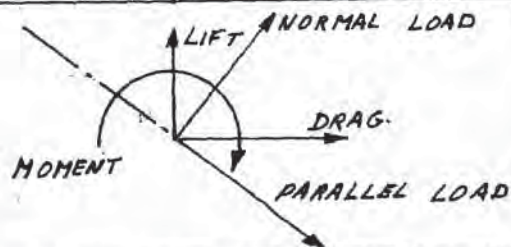
The max. drag load is obtained in the zero thrust case and the max. forward load in the max. thrust case.

The max. upward load normal to the model occurs at $\alpha = 35^\circ$.

The hovering cases are not critical so; only the transition cases will be used to check the model support structure.

SUMMARY OF LOADING ON THE MODEL

| LOADING CASES | AIRLOADS | | | NET LOADS. | |
|---------------------------------|------------|------------|----------------|----------------------|------------------------|
| | LIFT lb | DRAG lb | MOMENT inlb | NORMAL LOAD lb | PARALLEL LOAD lb |
| HOVERING - $\alpha = 0^\circ$ | 322 ↑ | | | 164 ↓ | |
| HOVERING - $\alpha = 20^\circ$ | 322 ↑ | 48.3 → | 853 G | 189.5 ↓ | 3.8 → |
| TRANSITION $\alpha = -10^\circ$ | 61.2 ↓ | 16.32 → | 4320 G | 546.13 ↓ | 29.22 ← |
| " ZERO THRUST | 10.2 ↑ | 10.2 → | 1440 G | 189.8 ↓ | 10.2 → |
| " MAX. THRUST | | | | 486 ↓ | 141 ← |
| " $\alpha = +20^\circ$ | 428 ↑ | 122.5 → | 1295 J | 30.2 ↓ | 37 → |
| " " + 35° | 570 ↑ | 245 → | 2300 J | 156 ↑ | 21.2 ← |
| " " + 45° * | 367 ↑ | 208 → | 4230 J | 21 ↓ | 38 → |

* $q = 18 \text{ PSF.}$ +VE SIGNSWRITTEN BY

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -4-3 MODEL SUPPORT STRUCTURE LOADS4-3-1 LOADING CONSIDERATIONS

Since the model support structure is entirely shielded from the airflow, the only loads applied to it are its own weight and the loads coming from the model.

The model support structure is supported on the 3 balance struts. The two main balance struts take vertical and horizontal loads and the rear balance strut takes vertical load only.

Side loads on the model structure are due mostly to pressure in the delivery pipes. The side load due to model airload has been estimated not to exceed 50 lb.

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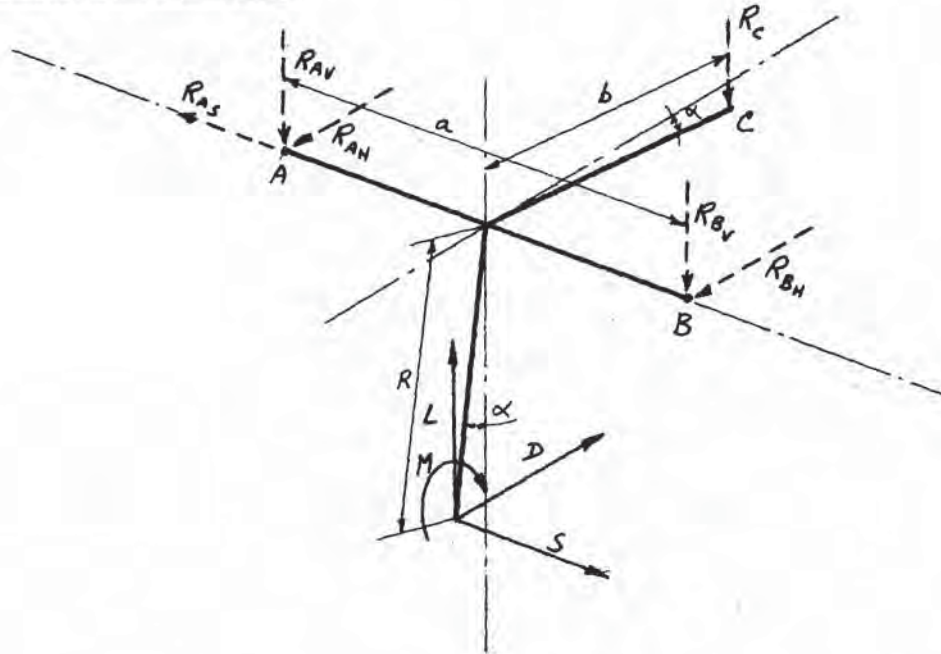
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-3 MODEL SUPPORT STRUCTURE LOADS4-3-2 MODEL LOADS & REACTIONSEQUATIONS OF EQUILIBRIUM.

$$R_{AV} = \frac{L}{2} + \frac{M}{2b} - \frac{SR}{a} \cos \alpha + \left[\frac{LR \sin \alpha - DR \cos \alpha}{2b \cos \alpha} \right] = \frac{L}{2} + R \left[\frac{L}{2b} \tan \alpha - \frac{D}{2b} - \frac{S}{a} \cos \alpha \right] + \frac{M}{2b}$$

$$R_{BV} = \frac{L}{2} + R \left[\frac{L}{2b} \tan \alpha - \frac{D}{2b} + \frac{S}{a} \cos \alpha \right] + \frac{M}{2b}$$

$$R_C = -\frac{R}{b} \left[L \tan \alpha - D \right] - \frac{M}{b}$$

$$R_{AH} = \frac{D}{2} - \frac{SR}{a} \sin \alpha$$

$$R_{BH} = \frac{D}{2} + \frac{SR}{a} \sin \alpha$$

$$R_{AS} = S$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-3 MODEL SUPPORT STRUCTURE LOADS4-3-2 MODEL LOADS & REACTIONSEQUATIONS OF EQUILIBRIUM - CONT'D.

We have: $a = 80"$ $b = 48"$ $R = 50"$

furthermore: $S = 50^{lb}$ assumed for all cases.
and $\alpha = -10^\circ, 0^\circ, 20^\circ \text{ \& } 45^\circ$

Then, Substituting

$$R_{AV} = \frac{L}{2} + \frac{M}{96} + .522 L \tan \alpha - .522 D - 31.25 \cos \alpha$$

$$R_{BV} = \frac{L}{2} + \frac{M}{96} + .522 L \tan \alpha - .522 D + 31.25 \cos \alpha$$

$$R_C = -1.042 [L \tan \alpha - D] - \frac{M}{48}$$

$$R_{AH} = \frac{D}{2} - 31.25 \sin \alpha$$

$$R_{BH} = \frac{D}{2} + 31.25 \sin \alpha$$

$$R_{AS} = 50^{lb}$$

LOADING CONDITIONS

| α | -10° | 0 | 0 MAX. THRUST | 20° | 45° g = 18 PSF. |
|---------------|-------------|-------|------------------|------------|---------------------------|
| L | -61.20 | 10.2 | 0 | 428 | 367 |
| D | 16.32 | 10.2 | -141 | 122.5 | 208 |
| M | -4320 | -1440 | 0 | 1295 | 4230 |
| $\sin \alpha$ | -.1737 | 0 | 0 | .342 | .707 |
| $\cos \alpha$ | .985 | 1.0 | 1.0 | .940 | .707 |
| $\tan \alpha$ | -.176 | 0 | 0 | .364 | 1.0 |

Ref: SECTION 4-2-4

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-3 MODEL SUPPORT STRUCTURE LOADS.4-3-2 MODEL LOADS & REACTIONS.CALCULATION OF LOADS.-10° CASE-

$$R_{AV} = -\frac{61.2}{2} - \frac{4320}{96} + .522(-61.20)(-.176) - (.522 \times 16.32) - (31.25 \times .985)$$

$$= -30.6 - 45 + 5.62 - 8.52 - 30.8 = \underline{\underline{-109.30}}^{lb} \quad \uparrow$$

$$R_{BV} = -30.6 - 45 + 5.62 - 8.52 + 30.8 = \underline{\underline{-47.70}}^{lb} \quad \uparrow$$

$$R_C = -1.042 \left[-21.20 \times -.176 - 16.32 \right] - \frac{-4320}{48} = +5.80 + 90 = \underline{\underline{+95.80}}^{lb} \quad \downarrow$$

Check on total vertical load: $-109.30 - 47.70 + 95.80 = 61.2^{lb}$ @ 61.2. OK

$$R_{AH} = \frac{16.32}{2} - 31.25(-.1737) = 8.16 + 5.43 = \underline{\underline{13.59}}^{lb} \quad \leftarrow$$

$$R_{BH} = \frac{16.32}{2} + 31.25(-.1737) = 8.16 - 5.43 = \underline{\underline{2.73}}^{lb} \quad \leftarrow$$

Check on total horizontal load: $13.59 + 2.73 = 16.32$ @ 16.32. OK.

$$R_{AS} = \underline{\underline{50}}^{lb} \quad \nearrow$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELA-3 MODEL SUPPORT STRUCTURE LOADSA-3-2 MODEL LOADS & REACTIONS.CALCULATION OF LOADS - CONT'D.0° CASE.

$$R_{AV} = \frac{10.2}{2} - \frac{1440}{96} + .522 \times 10.2 \times 0 - .522 \times 10.2 - 31.25 \times 1.0 =$$

$$5.1 - 15 + 0 - 5.32 - 31.25 = \underline{\underline{-46.47}} \text{ lb } \uparrow$$

$$R_{BV} = 5.1 - 15 + 0 - 5.32 + 31.25 = \underline{\underline{+16.03}} \text{ lb } \downarrow$$

$$R_C = -1.042 [10.2 \times 0 - 10.2] - \frac{-1440}{48} =$$

$$+10.62 + 30 = \underline{\underline{+40.62}} \text{ lb } \downarrow$$

Check on total vertical load: $40.62 + 16.03 - 46.47 = 10.18 @ 10.20.$

$$R_{AH} = \frac{10.2}{2} - 31.25(0) = \underline{\underline{5.1}} \text{ lb } \leftarrow$$

$$R_{BH} = \frac{10.2}{2} + 31.25(0) = \underline{\underline{5.1}} \text{ lb } \leftarrow$$

Check on total horizontal load: $5.1 + 5.1 = 10.2 @ 10.2.$

$$R_{AS} = \underline{\underline{50}} \text{ lb } \nwarrow$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-3 MODEL SUPPORT STRUCTURE LOADS4-3.2 MODEL LOADS & REACTIONS.CALCULATION OF LOADS - CONT'D.0° CASE - MAX. THRUST -

$$R_{AV} = \frac{0}{2} - \frac{0}{96} + .522 \times 0 \times 0 - .522(-141) - (31.25 \times 1)$$

$$= + 73.5 - 31.25 = \underline{\underline{42.25 \text{ lb}}} \downarrow$$

$$R_{BV} = 73.5 + 31.25 = \underline{\underline{104.5 \text{ lb}}} \downarrow$$

$$R_C = -1.042 [0 \times 0 - (-141)] - \frac{0}{48} = \underline{\underline{-147 \text{ lb}}} \uparrow$$

Check on total Vert. load: $104.5 + 42.25 - 147 = -.25 @ 0.$

$$R_{AH} = \frac{-141}{2} - 31.25 \times 0 = \underline{\underline{-70.5 \text{ lb}}} \rightarrow$$

$$R_{BH} = \frac{-141}{2} + 31.25 \times 0 = \underline{\underline{-70.5 \text{ lb}}} \rightarrow$$

Check on total Horizontal load: $-70.5 - 70.5 = -141 \text{ lb} @ -141 \text{ lb}$

$$R_{AS} = \underline{\underline{50 \text{ lb}}} \swarrow$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-3 MODEL SUPPORT STRUCTURE LOADS4-3-2 MODEL LOADS & REACTIONSCALCULATION OF LOADS - CONT'D.20° CASE -

$$R_{AV} = \frac{428}{2} + \frac{1535}{96} + (.522 \times 428 \times .364) - (.522 \times 122.5) - (31.25 \times .94) =$$

$$= 214 + 16 + 81.3 - 64 - 29.4 = \underline{217.9}^{lb} \quad \downarrow$$

$$R_{BV} = \frac{428}{2} + \frac{1535}{96} + (.522 \times 428 \times .364) - (.522 \times 122.5) + (31.25 \times .94) =$$

$$= 214 + 16 + 81.3 - 64 + 29.4 = \underline{276.7}^{lb} \quad \downarrow$$

$$R_C = -1.042 [428 \times .364 - 122.5] - \frac{1535}{48} = -34.9 - 32 = \underline{-66.9}^{lb} \quad \uparrow$$

Check on Total Vertical Load: $217.9 + 276.7 - 66.9 = 427.7^{lb} \quad @ 428.$

$$R_{AH} = \frac{122.5}{2} - 31.25 \times .342 = 61.25 - 10.68 = \underline{50.57}^{lb} \quad \leftarrow$$

$$R_{BH} = \frac{122.5}{2} + 31.25 \times .342 = 61.25 + 10.68 = \underline{71.93}^{lb} \quad \leftarrow$$

Check on total horizontal load: $50.57 + 71.93 = 122.5 \quad @ 122.5$

$$R_{AS} = \underline{50}^{lb} \quad \nwarrow$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-3 MODEL SUPPORT STRUCTURE LOADS4-3-2 MODEL LOADS & REACTIONSCALCULATION OF LOADS - CONT'D.45° CASE -

$$R_{AV} = \frac{367}{2} + \frac{4230}{96} + (.522 \times 367 \times 1.0) - (.522 \times 208) - (31.25 \times .707) =$$

$$183.5 + 44 + 192 - 108.5 - 22.1 = \underline{288.9}^{lb} \quad \downarrow$$

$$R_{BV} = \frac{367}{2} + \frac{4230}{96} + (.522 \times 367 \times 1.0) - (.522 \times 208) + (31.25 \times .707) =$$

$$183.5 + 44 + 192 - 108.5 + 22.1 = \underline{333.1}^{lb} \quad \downarrow$$

$$R_C = -1.042 \left[(367 \times 1) - 208 \right] - \frac{4230}{48} = -166 - 88.2 = \underline{-254.2}^{lb} \quad \uparrow$$

check on total vertical load: $288.9 + 333.1 - 254.2 = 367.8$ @ 367

$$R_{AH} = \frac{208}{2} - (31.25 \times .707) = 104 - 22.1 = \underline{81.9}^{lb} \quad \leftarrow$$

$$R_{BH} = \frac{208}{2} + (31.25 \times .707) = 104 + 22.1 = \underline{126.1}^{lb} \quad \leftarrow$$

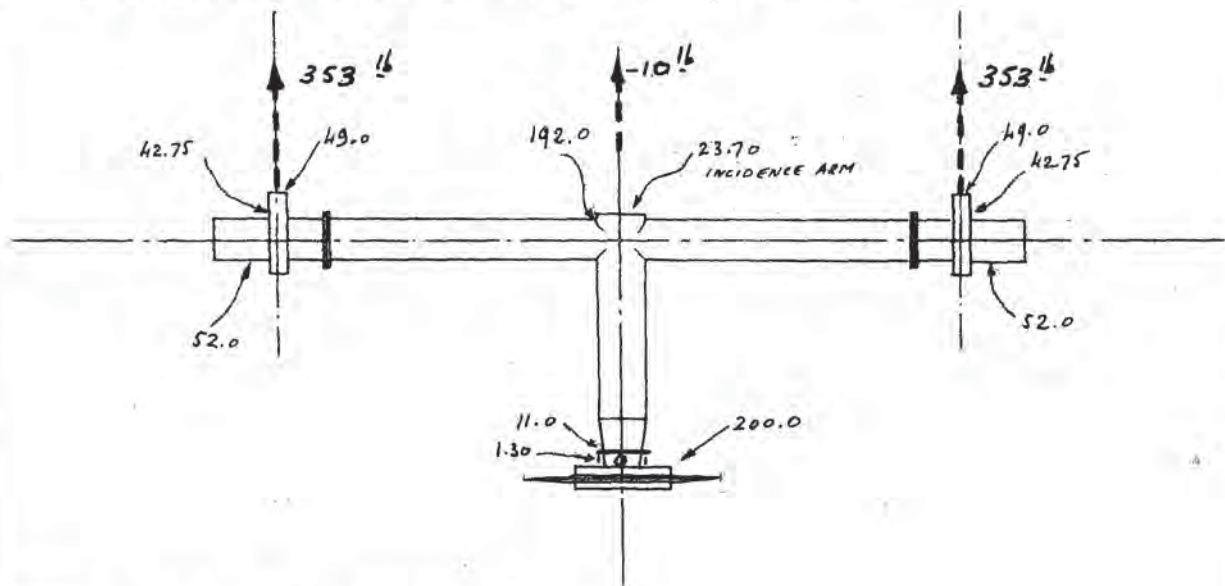
check on total horizontal load: $81.9 + 126.1 = 208$ @ 208

$$R_{AS} = 50^{lb} \quad \nwarrow$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.4-3 MODEL SUPPORT STRUCTURE LOADS4-3-3 LOADS DUE TO STATIC WEIGHT & REACTIONS.MODEL MOUNT - TOTAL WEIGHT, INCLUDING MODEL.TOTAL WEIGHT OF ASSEMBLY -

$$200 + 1.30 + 11.0 + 192 + 24.60 + 2(49 + 42.75 + 52) =$$

$$200 + 1.30 + 11.0 + 192 + 24.60 + 287.5 = \underline{\underline{715.80 \text{ lb}}}$$

Load on balance struts -

Main struts:

$$- \frac{715.8 - 10}{2} \approx - 353 \text{ lb}$$

Incidence strut:

$$- 24 \frac{20}{48} = - 10 \text{ lb}$$

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Moment about point O:

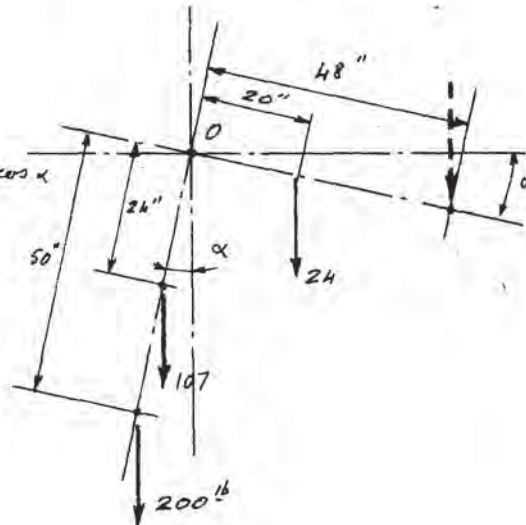
$$\begin{aligned}
 & -(107 \times 24 \sin \alpha) - (200 \times 50 \sin \alpha) + (24 \times 20) \cos \alpha \\
 & = -\sin \alpha (107 \times 24 + 200 \times 50) + 480 \cos \alpha \\
 & = -12570 \sin \alpha + 480 \cos \alpha
 \end{aligned}$$

Reaction at incidence strut:

$$\frac{-12570 \sin \alpha + 480 \cos \alpha}{48 \cos \alpha} = -262 \tan \alpha - 10$$

Reaction when $\alpha = -10^\circ$:

$$-10 + 262 \tan(-10^\circ) = \underline{\underline{-56.2 \text{ lb}}}$$



Reactions on main struts:

$$-\left(\frac{715.8 - 56.2}{2}\right) = \underline{\underline{-329.8 \text{ lb}}}$$

+20°

Reaction at incidence strut:

$$262 \tan(\alpha) - 10 = 262 \tan(20^\circ) - 10 = \underline{\underline{85.2 \text{ lb}}}$$

Reactions on main struts

$$-\left(\frac{715.8 + 85.2}{2}\right) = \underline{\underline{-400.5 \text{ lb}}}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-3 MODEL SUPPORT STRUCTURE LOADS4-3-3 LOADS DUE TO STATIC WEIGHT & REACTIONSREACTION ON INCIDENCE STRUT FOR ANGLES $\alpha \neq 0$ CONT'D+ 45°

Reaction at incidence strut:

$$-262 \tan \alpha + 10 = -262 \tan 45^\circ + 10 = -252 \text{ lb}$$

Reactions on main struts:

$$- \frac{715.8 + 252}{2} = -483.9 \text{ lb}$$

SUMMARY OF STATIC STRUT REACTIONS-

| α° | MAIN STRUT | INCIDENCE STRUT. |
|----------------|------------|------------------|
| -10 | -329.8 | -56.2 |
| 0 | -353.0 | -10.0 |
| 20 | -400.5 | -85.2 |
| 45 | -483.9 | -252 |

ALL LOADS IN lb

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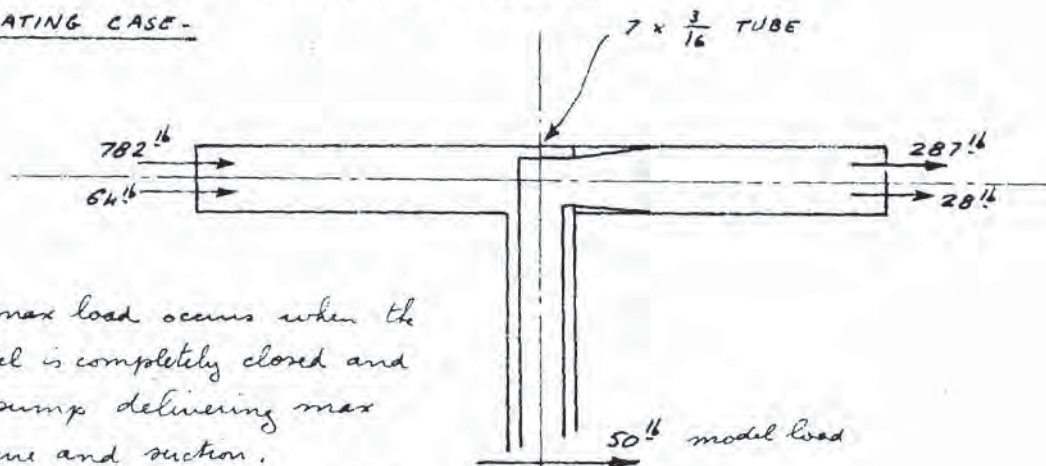
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-3 MODEL SUPPORT STRUCTURE LOADS4-3-4 LOADS DUE TO PRESSURE & SUCTION.HORIZONTAL LOAD ON MODEL SUPPORT.OPERATING CASE-

The max load occurs when the model is completely closed and the pump delivering max pressure and suction.

In the operating case, the load decrease to 782^{lb} static load and 64^{lb} reaction to mass flow on the pressure side and 287^{lb} static load and 28^{lb} reaction to mass flow on the suction side:

$$\text{same: } 782 + 64 + 28 + 287 = \underline{\underline{1211 \text{ lb}}}$$

PRESSURE CASE:

$$\text{TUBE AREA: } [7 - (2 \times .187)]^2 \frac{\pi}{4} = 34.5 \text{ in}^2$$

MAX. ABS. PRESSURE : 44.7 PSIA

MIN. ABS. PRESSURE : 6.34 PSIA

}

$$\text{TOTAL LOAD: } (44.7 - 6.34) 34.50 + 50 = \underline{\underline{1372 \text{ lb}}}$$

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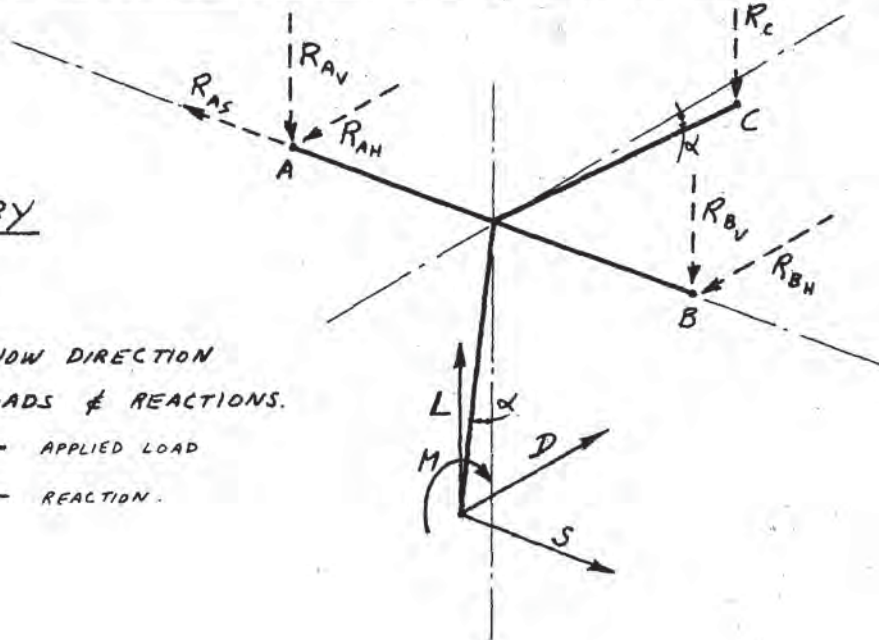
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-3 MODEL SUPPORT STRUCTURE LOADS4-3-5 NET LOADS & REACTIONSBALANCE STRUTS LOADS DUE TO MODEL LOADS ONLY -SUMMARY

ARROWS SHOW DIRECTION
OF +VE LOADS & REACTIONS.

———— APPLIED LOAD
----- REACTION.



| α | -10° | 0 | 0 MAX. THRUST. | 20° | 45° |
|------------------------------|-------------|--------|-------------------|------------|------------|
| R_{AV} | -109.31 | -46.47 | 42.25 | 217.9 | 288.9 |
| R_{BV} | -47.71 | 16.03 | 104.5 | 276.7 | 333.1 |
| R_C | -95.82 | 40.62 | -147 | -66.9 | -254.2 |
| R_{AH} | 13.59 | 5.1 | -70.5 | 50.57 | 81.9 |
| R_{BH} | 2.73 | 5.1 | -70.5 | 71.93 | 126.1 |
| R_{AS} | 50 | 50 | 50 | 50 | 50 |
| R_{AS} TOTAL OPERATING. | | | 1211 | | |
| PRESS. CASE | 1372 | 1372 | | 1372 | 1372 |

-VE REACTION IS A DOWN OR FORWARD LOAD ON THE STRUT

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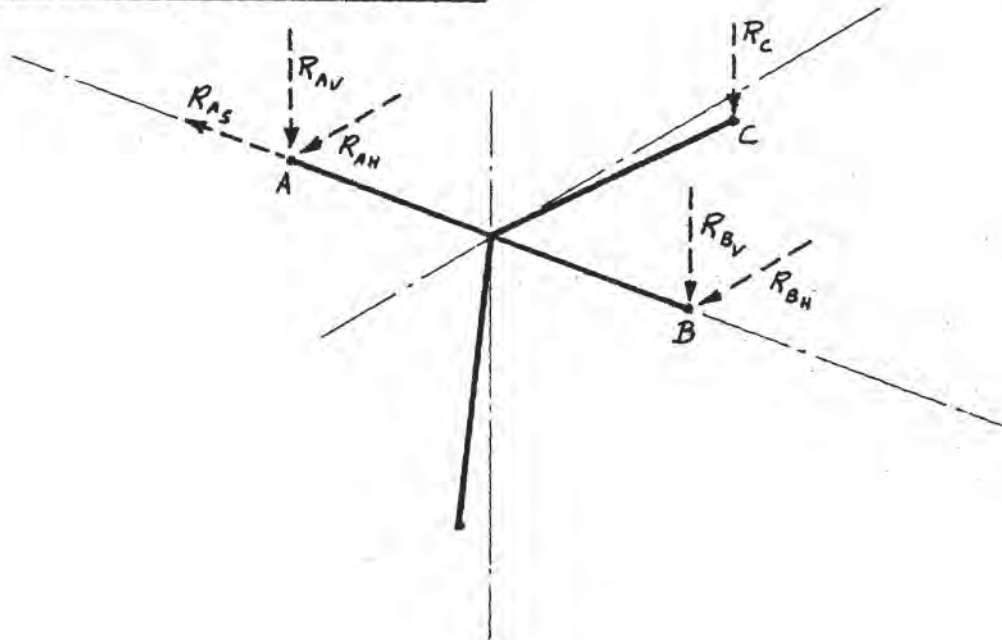
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-3 MODEL SUPPORT STRUCTURE LOADS4-3-5 NET LOADS & REACTIONS -NET LOADS ON BALANCE STRUTS

| α | -10° | 0 | 0 MAX. THRUST. | 20° | 45° 18 g. |
|----------|-------------|---------|-------------------|------------|---------------------|
| R_{AV} | -439.11 | -399.47 | -310.75 | -182.6 | -195.0 |
| R_{BV} | -377.51 | -336.97 | -248.5 | -123.8 | -150.8 |
| R_C | +39.62 | +30.62 | -157.0 | +18.3 | -2.2 |
| R_{AH} | +13.59 | +5.10 | -70.5 | +50.57 | +81.9 |
| R_{BH} | +2.73 | +5.10 | -70.5 | +71.93 | +126.1 |

- REACTION R_{AS} is not shown here as it is not taken by the struts (See Fairing loads).
- Reactions R_{AV} & R_{BV} and R_{AH} & R_{BH} are interchangeable depending on the direction of the side load on the model.
- In the above table: -ve reaction is a down or forward load on the strut.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-4FAIRING LOADS4-4-1LOADING CONSIDERATIONS

The fairings are loaded by aerodynamic drag force and static weight only. A side load due to lift on the vertical fairing caused by a deviation of the tunnel airflow has been considered.

A drag coef. $C_D = 1.0$ has been taken for the horizontal tube. Aerodynamic characteristics for the vertical fairing at an angle of incidence $\alpha = 5^\circ$ have been estimated by comparison with other thick airfoils.

The loads on the fairings are taken by the balance strut fairings, the main strut fairings taking vertical and horizontal loads and the rear strut fairing taking vertical load only.

The part of fairing tube between tunnel wall and balance struts are considered as simply supported beams their loading dividing between the 2 supports.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-4 FAIRING LOADS4-4-2 LOADS DUE TO AERODYNAMIC FORCES

For a Circular Cylinder, the drag coef. $C_D \approx 1.0$

Thus, for a 10" tube, the drag per running foot is:

$$D = C_D S q = 1.0 \times .833 q = .833 q$$

Hence: at the max speed of the tunnel: ($q = 30 \text{ PSF}$)

$$D = 30 \times .833 = 25 \frac{\text{lb}}{\text{ft}}$$

and at the reduced speed: ($q = 18 \text{ PSF}$)

$$D = 18 \times .833 = 15 \frac{\text{lb}}{\text{ft}}$$

Length of tube between balance struts: 80"

Length of tube outside balance struts: $230 - 80 = 150"$

Thus, on balance strut fairings, the load is:

$$\begin{aligned} \text{at } \underline{30q}: \quad 25 \left[\frac{80}{2 \times 12} + \frac{150}{4 \times 12} \right] &= 25 (3.33 + 3.13) = \\ &= 25 \times 6.46 = \underline{164 \frac{\text{lb}}{\text{ft}}} \rightarrow \end{aligned}$$

and load on tunnel walls:

$$25 \frac{150}{4 \times 12} = 25 \times 3.13 = \underline{78.2 \frac{\text{lb}}{\text{ft}}} \rightarrow$$

$$\begin{aligned} \text{at } \underline{18q}: \quad \text{on strut fairings: } 15 \times 6.46 &= \underline{97 \frac{\text{lb}}{\text{ft}}} \rightarrow \\ \text{on tunnel wall: } 15 \times 3.13 &= \underline{46.9 \frac{\text{lb}}{\text{ft}}} \rightarrow \end{aligned}$$

Drag on vertical fairing

The drag coef for the streamlined shape will be taken at:

$$C_D = .20$$

$$\text{Frontal area: } \frac{42 \times 11}{144} = 3.2 \text{ ft}^2$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-4 FAIRING LOADS.4-4-2 LOADS DUE TO AERODYNAMIC FORCESDrag on vertical fairing: cont'd.

$$\text{Drag force: } .20 \times 3.2 \times q = .64 q.$$

$$\text{High speed case: } q = 30 \text{ PSF.}$$

$$D = .64 \times 30 = 19.20 \text{ lb.}$$

$$\text{Low speed case: } q = 18 \text{ PSF.}$$

$$D = .64 \times 18 = 11.50 \text{ lb.}$$

Load on strut fairings:

$$q = 30 \text{ PSF.}$$

$$\frac{19.20}{2} = \underline{\underline{9.60 \text{ lb.}}} \rightarrow$$

$$q = 18 \text{ PSF.}$$

$$\frac{11.50}{2} = \underline{\underline{5.75 \text{ lb.}}} \rightarrow$$

REACTION ON INCIDENCE STRUT FAIRING.

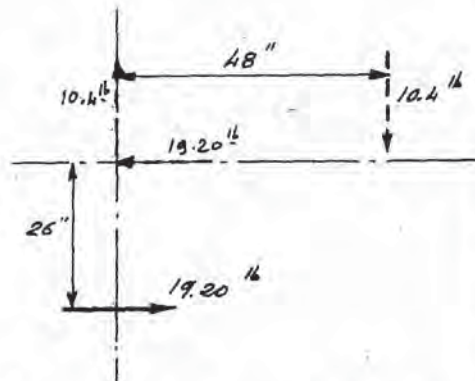
$$\alpha = 0^\circ.$$

$$(30 q) \quad 19.20 \frac{26}{48} = 10.4 \text{ lb.}$$

$$(18 q) \quad 11.50 \frac{26}{48} = 6.22 \text{ lb.}$$

$$\alpha = 45^\circ$$

At this angle the airload on the fairing will be approximately balanced by that on the cross fairing. Hence the reaction will be small and can be neglected.



$$\alpha = 20^\circ$$

Since the reaction at $\alpha = 0^\circ$ is only 10 lb it will be conservative to assume the same value for $\alpha = 20^\circ$.

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ON MAIN STRUTS FAIRINGS:

$$q = 30 \text{ PSF} : 164 + 9.60 = \underline{173.6}^{\text{lb}}$$

$$q = 18 \text{ PSF} : 97 + 5.75 = \underline{102.75}^{\text{lb}}$$

ON TUNNEL WALL:

$$q = 30 \text{ PSF} : \underline{78.2}^{\text{lb}}$$

$$q = 18 \text{ PSF} : \underline{46.9}^{\text{lb}}$$

VERTICAL LOADS:

$$q = \begin{cases} \text{ON MAIN STRUTS : } \underline{5.2}^{\text{lb}} \downarrow \\ 30 \text{ PSF} \left\{ \begin{array}{l} \text{ON REAR STRUT : } \underline{10.4}^{\text{lb}} \uparrow \end{array} \right. \end{cases}$$

direction of applied load.

$$q = \begin{cases} \text{ON MAIN STRUTS : } 3.11^{\text{lb}} \downarrow \\ 18 \text{ PSF} \left\{ \begin{array}{l} \text{ON REAR STRUT : } 6.22^{\text{lb}} \downarrow \end{array} \right. \end{cases}$$

" "

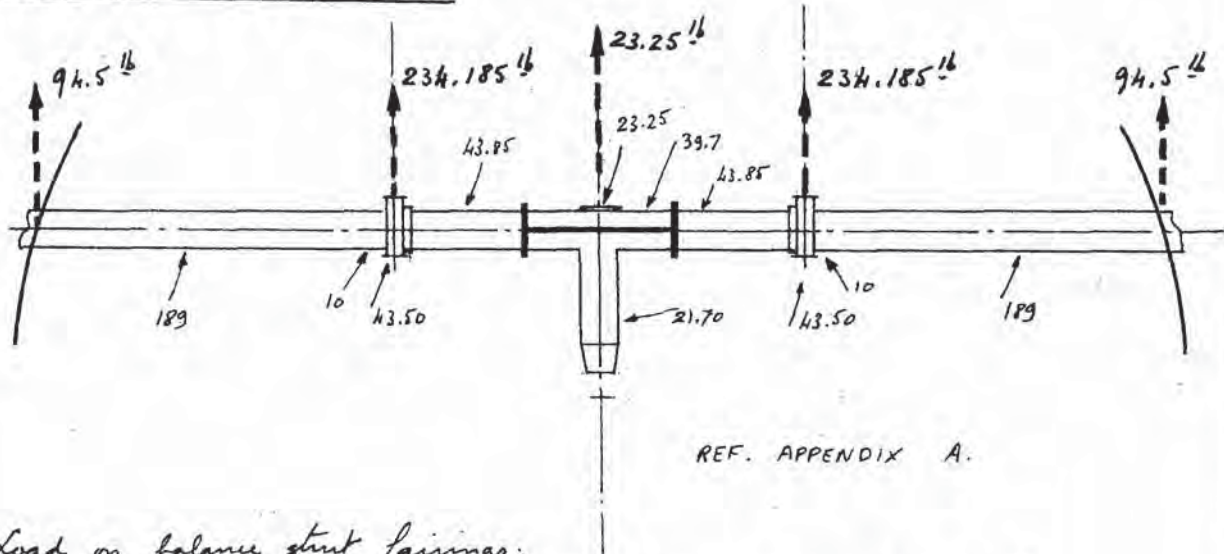
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -4-4 FAIRING LOADS4-4-3 LOADS DUE TO STATIC WEIGHTSFAIRINGS - TOTAL WEIGHT.

Load on balance strut fairings:

$$43.50 + 10 + \frac{189}{2} + 43.85 + \frac{23.25}{2} + \frac{39.7}{2} + \frac{21.70}{2} = 234.185 \text{ lb}$$

Load on tunnel wall attachment:

$$\frac{189}{2} = 94.5 \text{ lb}$$

TOTAL WEIGHT OF FAIRINGS.

$$(189 \times 2) + (10 \times 2) + (43.5 \times 2) + (43.85 \times 2) + (23.25 \times 2) + 39.7 + 21.70 =$$

$$378 + 20 + 87 + 87.60 + 46.50 + 39.7 + 21.70 = \underline{\underline{680.50 \text{ lb}}}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.H-4 FAIRING LOADSH-4-3 LOADS DUE TO STATIC WEIGHT & REACTIONSREACTION ON INCIDENCE STRUT FAIRING FOR ANGLES $\alpha \neq 0$

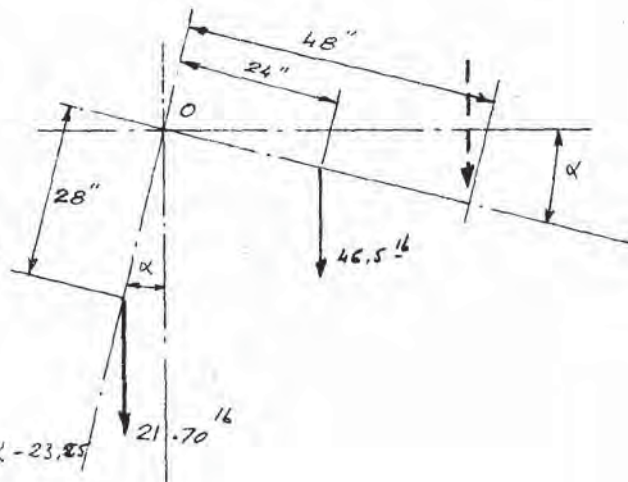
Moment about point O.

$$21.70 \times 28 \sin \alpha - 24 \times 46.5 \cos \alpha$$

$$= 608 \sin \alpha - 1118 \cos \alpha$$

Reaction at incidence strut

$$\frac{608 \sin \alpha - 1118 \cos \alpha}{48 \cos \alpha} = 12.65 \tan \alpha - 23.25$$



$$\alpha = -10^\circ$$

Reaction at incidence strut:

$$12.65 \tan(-10^\circ) - 23.25 =$$

$$= -2.23 - 23.25 = -25.48 \text{ lb}$$

Reactions at main struts

$$-234.20 + \frac{2.23}{2} = -233.10 \text{ lb}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELA-4 FAIRING LOADSA-4-3 LOADS DUE TO STATIC WEIGHT & REACTIONSREACTION ON INCIDENCE STRUT FAIRING FOR ANGLES $\alpha \neq 0$ - CONT'D.

$\alpha = 20^\circ$

Reaction at incidence strut

$12.65 \tan 20^\circ - 23.25 =$

$= -23.25 + 4.6 = -18.65 \frac{lb}{in}$

Reactions at main struts

$-234.20 - \frac{4.6}{2} = -236.50 \frac{lb}{in}$

$\alpha = 45^\circ$

Reaction at incidence strut:

$12.65 \tan 45^\circ - 23.25 =$

$= -23.25 + 12.65 = -10.60 \frac{lb}{in}$

Reactions at main struts

$-234.20 - \frac{12.65}{2} = -240.50 \frac{lb}{in}$

SUMMARY OF STATIC LOADS ON STRUT FAIRINGS & TUNNEL WALLS.

| α° | MAIN STRUT FAIRING | INCIDENCE STRUT FAIRING | TUNNEL WALL |
|----------------|--------------------|-------------------------|-------------|
| -10 | 233.10 | 25.5 | 94.5 |
| 0 | 234.20 | 23.2 | 94.5 |
| 20 | 236.50 | 18.6 | 94.5 |
| 45 | 240.5 | 10.2 | 94.5 |

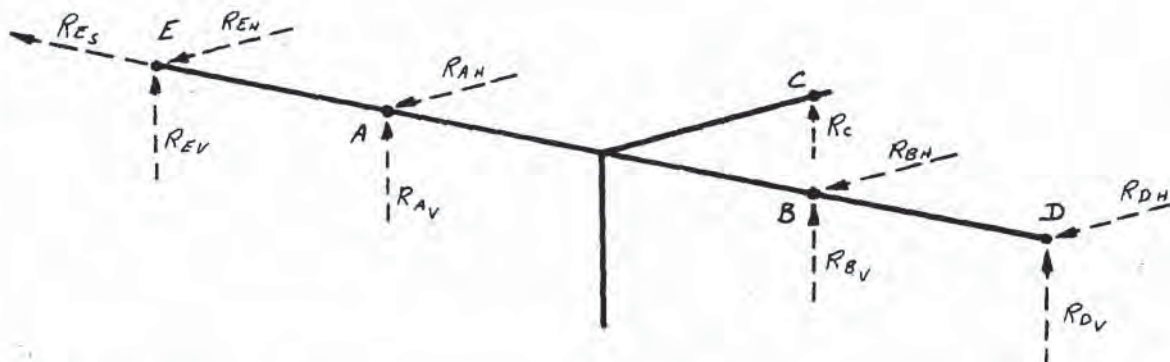
ALL LOADS IN $\frac{lb}{in}$

+VE LOADS ARE PULL ON FAIRINGS OR DOWN LOADS ON TUNNEL WALL.

| | | | | |
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-4 FAIRING LOADS4-4-4 NET LOADS & REACTIONS -

| REACTIONS α | -10° | 0° | 20° | 45° 189. |
|----------------------|-------------|-----------|------------|-----------------|
| R_{AV} | 238.3 | 239.4 | 241.7 | 243.6 |
| R_{BV} | 238.3 | 239.4 | 241.7 | 243.6 |
| R_{AH} | 173.6 | 173.6 | 173.6 | 102.7 |
| R_{BH} | 173.6 | 173.6 | 173.6 | 102.7 |
| R_C | 15.1 | 12.8 | 8.2 | 4.38 |
| R_{DV} | 94.5 | 94.5 | 94.5 | 94.5 |
| R_{EV} | 94.5 | 94.5 | 94.5 | 94.5 |
| R_{DH} | 78.2 | 78.2 | 78.2 | 46.9 |
| R_{EH} | 78.2 | 78.2 | 78.2 | 46.9 |
| R_{ES}^* OPERATING | 0 | 1211.0 | 0 | 0 |
| R_{ES}^* PRESSURE | 1372.0 | 1372.0 | 1372.0 | 1372.0 |

* REF. - 4-3.5

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -5-0MODEL STRESS ANALYSIS.5-1-1LOADING CONSIDERATIONS.

The aerodynamic loads developed in section 4 have been used together with pressure in the supply tubes, only to check the strength of the attachment of the model to its supporting structure (see sections 6 & 7)

Due to the robust nature of the model structure, stresses induced in the model by these external loads will be low and can be neglected. The validity of this statement is illustrated by the pessimistic assessment of the loads in the wing attachment bolts (section 5-2-1)

The highest stresses will be those due to the pressure differential between the interior and outside of the model.

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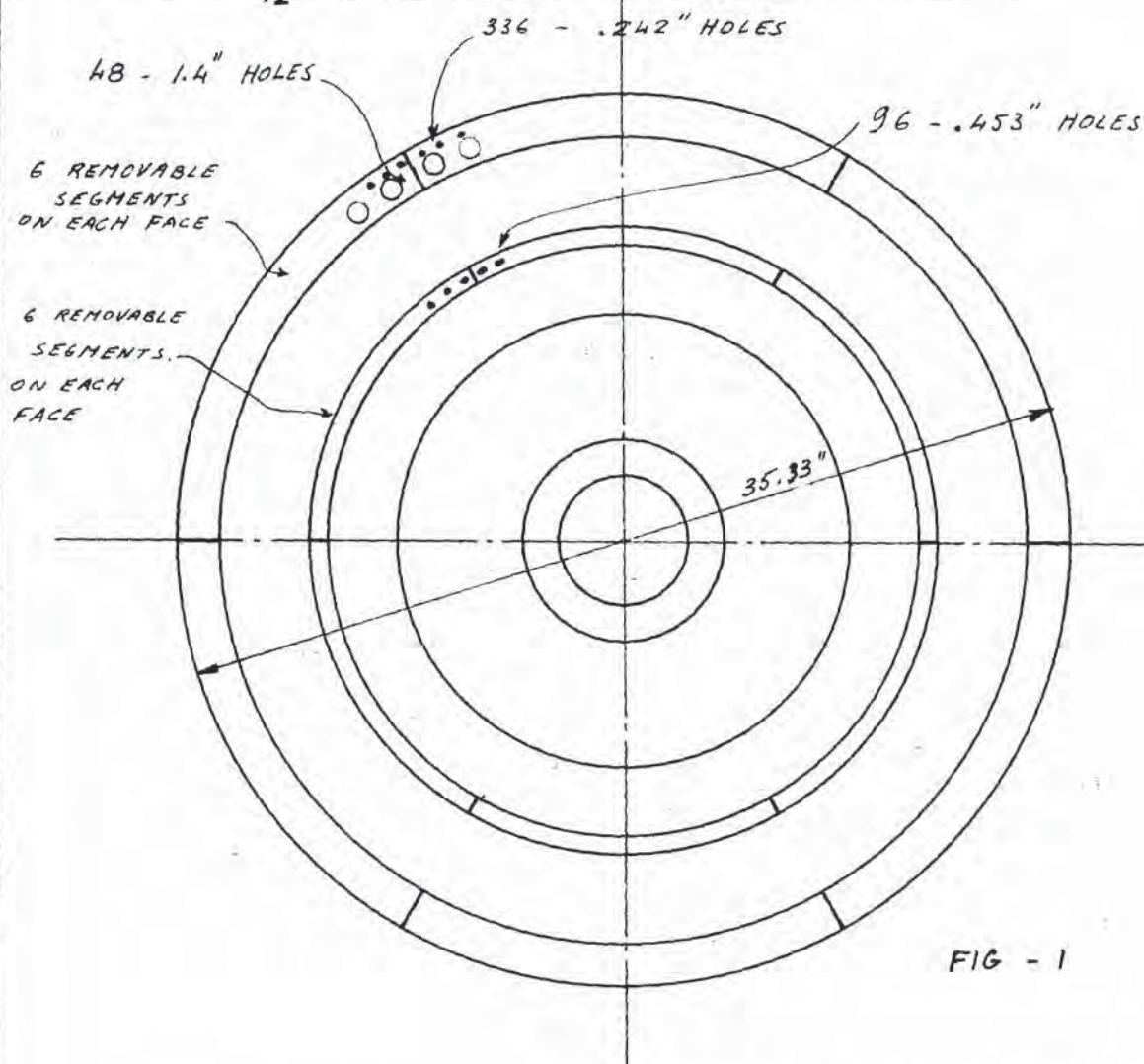
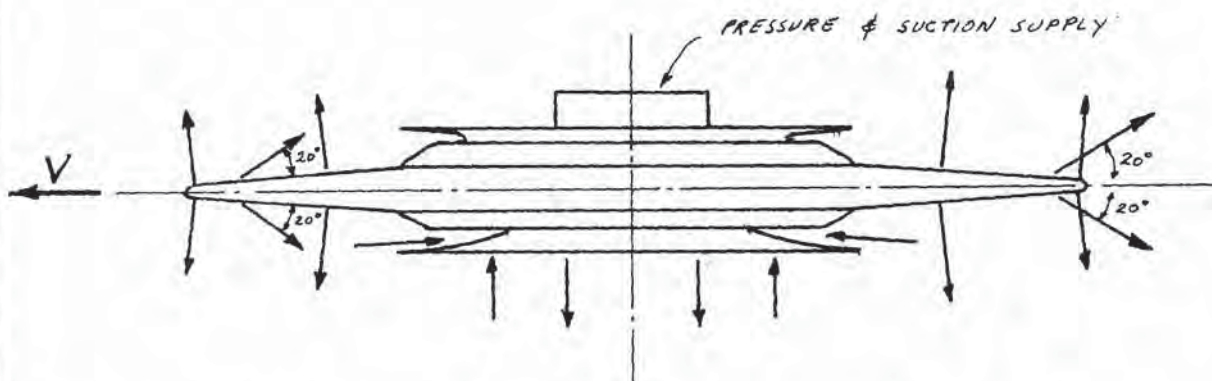
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL5-0 - FIG-8 - $\frac{1}{12}$ SCALE MODEL - SCHEMATIC DIAGRAM

FIG - 1

TUNNEL SPEED : $V = 158.8 \frac{\text{ft}}{\text{sec}}$ $q = 30 \text{ PSF.}$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL5-1-2 DIFFERENTIAL PRESSURE ON THE WING UPPER SURFACE.

MAX. internal pressure in the wing: 30.74 PSIA

Assume the A/C is at 45° incidence. and a pressure distribution giving an average value of $C_p = -5$ on the front part of the wing.

Assume also that the mean value of C_p over the first 3" after L.E. is $C_p = -10$.

Hence: the local pressure: $\Delta P = C_p q$

$$\Delta P_{AVE} = -5 \times 30 = -150 \text{ PSF} = -1.04 \text{ PSI}$$

$$\Delta P_{TIP} = -10 \times 30 = -300 \text{ PSF} = -2.08 \text{ PSI}$$

Hence total external pressure: $P_{AVE} = 14.7 - 1.04 = 13.66 \text{ PSI}$

$$P_{TIP} = 14.7 - 2.08 = 12.62 \text{ PSI}$$

Differential pressure taken by the wing structure:

$$\Delta P_{AVE} = 30.74 - 13.66 = 17.08 \text{ PSI}$$

$$\Delta P_{TIP} = 30.74 - 12.62 = 18.12 \text{ PSI}$$

A General stiffening of the wing will be carried out using 17.10 PSI and a local stiffening near the leading edge using 18.20 PSI.

With a load factor of 4, these pressures become:

$$17.1 \times 4 = \boxed{68.4 \text{ PSI}}$$

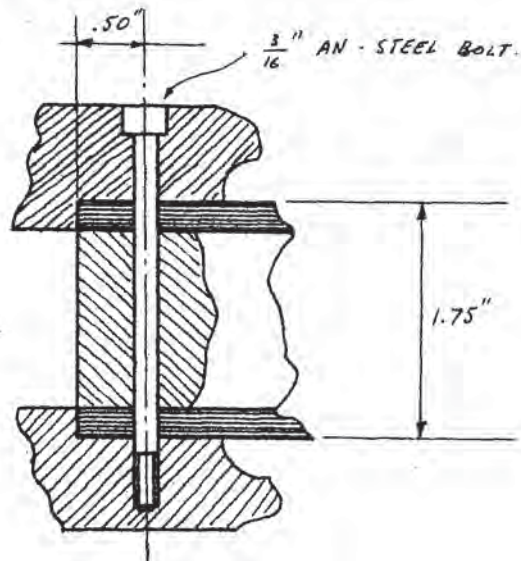
$$18.2 \times 4 = \boxed{72.8 \text{ PSI}}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL5-0 MODEL STRESS ANALYSIS5-2-1 WING ATTACHMENT BOLTS

As a covering stressing,
the bolt is assumed to take
in shear the moment calculated
from the diagram below under
an arbitrary pressure of 5 PSI
At the same time, it will be
considered under the tension due
to internal pressure of 68.4 PSI
on an area of 10 in^2



Hence: tension in the bolt:

$$68.4 \times 10 = 684.0 \text{ lb}$$

Area of the wing segment:

$$(2.04 + 4.6) \frac{9.8}{2} = 32.5 \text{ in}^2$$

Moment about the bolt:

$$4 \times 32.5 \times 5 \times 5.1 = 3308 \text{ in} \cdot \text{lb}$$

Shear on the bolt: $\frac{3308}{1.75} = 1890.0 \text{ lb}$

Strength of the $\frac{3}{16}$ " bolt as per AN-C-5: Tension: 2160 lb

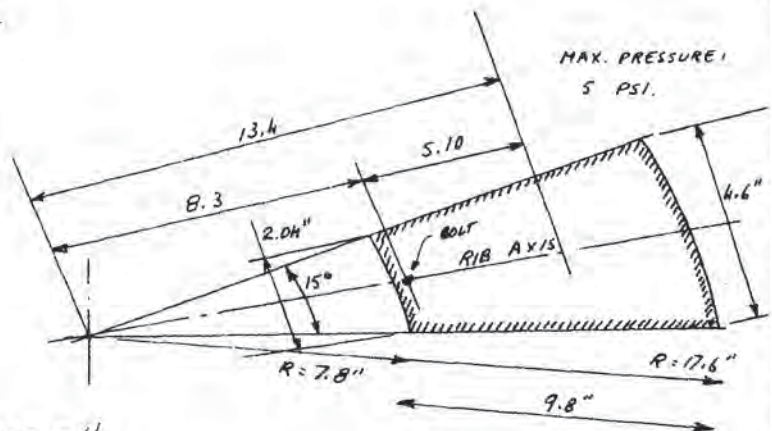
shear: 2070 lb

Combined loading: allowable tension:

$$Y = \sqrt{b^2 \left(1 - \frac{x^2}{a^2}\right)} = b \sqrt{1 - \frac{x^2}{a^2}}$$

$$Y = 2160 \sqrt{1 - \left(\frac{1890}{2070}\right)^2} = 2160 \times \sqrt{1 - .835} = 2160 \times .406 = 875 \text{ lb}$$

M.S. $\frac{875}{684.0} - 1 =$



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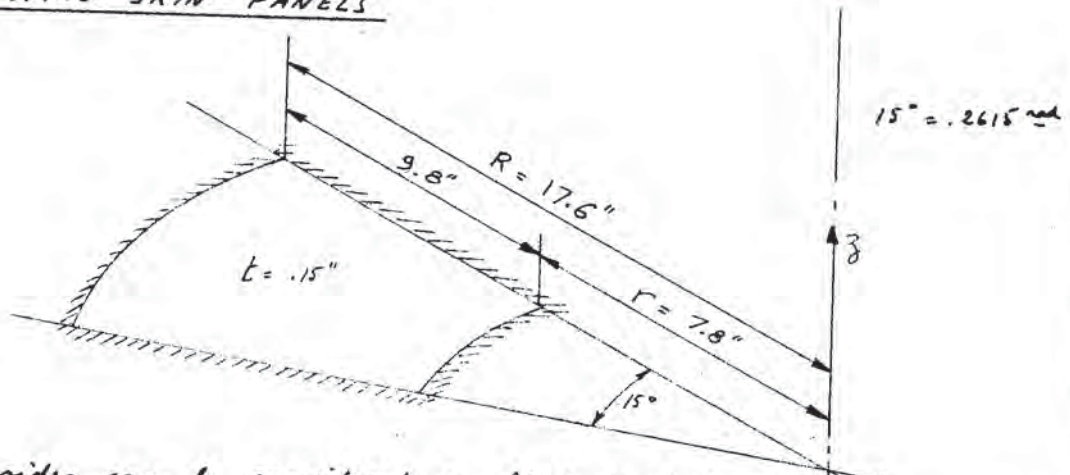
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL5-0 MODEL STRESS ANALYSIS5-2-2 WING SKIN PANELS

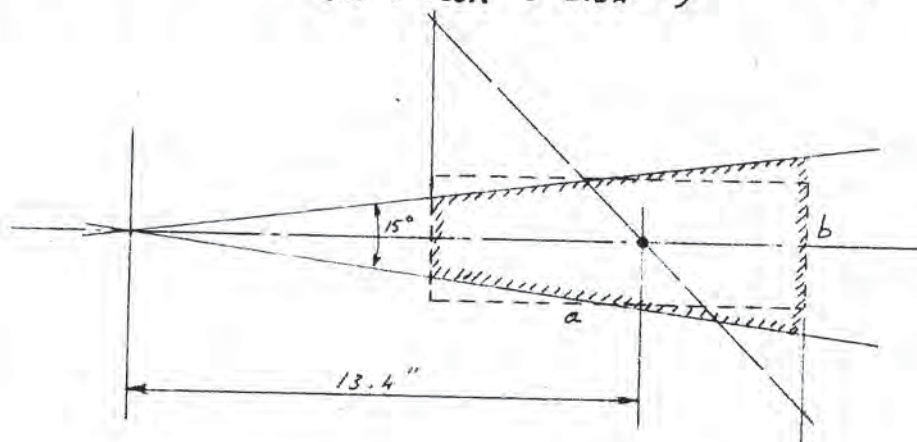
Assume:

- 1 - all sides can be considered as fixed against rotation
- 2 - all sides can be assumed held against deflection in z direction.

Area of panel: $\pi \frac{15}{360} (17.6^2 - 7.8^2) = \frac{\pi}{24} (310 - 61) = 32.5 \text{ in}^2$

Max pressure force on panel: $32.5 \times 17.10 = 556 \text{ lb}$

Length of arcs: $\left. \begin{array}{l} 17.6 \times .2615 = 4.6'' \\ 7.8 \times .2615 = 2.04'' \end{array} \right\} \text{mean length: } 3.32''$



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.5-0 MODEL STRESS ANALYSIS5-2-2 WING SKIN PANELS

Consider the rectangular plate shown in dotted line.

This plate is relatively thick and will take the load in bending rather than as a membrane.

we have: $b = 3.32''$ $a = 9.80''$ $\frac{b}{a} = .339$

Ref. Resistance des matériaux appliquee à l'aviation by Paul Vallat.

Max. bending stress in the plate: $f_{b_m} = A P \left(\frac{b}{t} \right)^2$

Max. deflection at the center: $\delta_M = C \frac{P b}{E(1-\nu^2)} \left(\frac{b}{t} \right)^3$

Ref. A from curve (2) Diagram 32-1 - $A = .50$

Ref. C " " (4) " " - $C = .212$

Thus: $f_{b_m} = .50 \times 17.10 \left(\frac{3.32}{.15} \right)^2 = 4190 \text{ PSI}$ @ 55000 PSI.

$$\delta_M = .212 \times \frac{17.10 \times 3.32}{30 \times 10^6 (1.069)} \left(\frac{3.32}{.15} \right)^3 = .000209''$$

Fully factored bending stress: $4 \times 4190 = 16780 \text{ PSI}$

M.S. $\frac{55000}{16780} - 1 = \underline{\hspace{2cm}}$ 2.28

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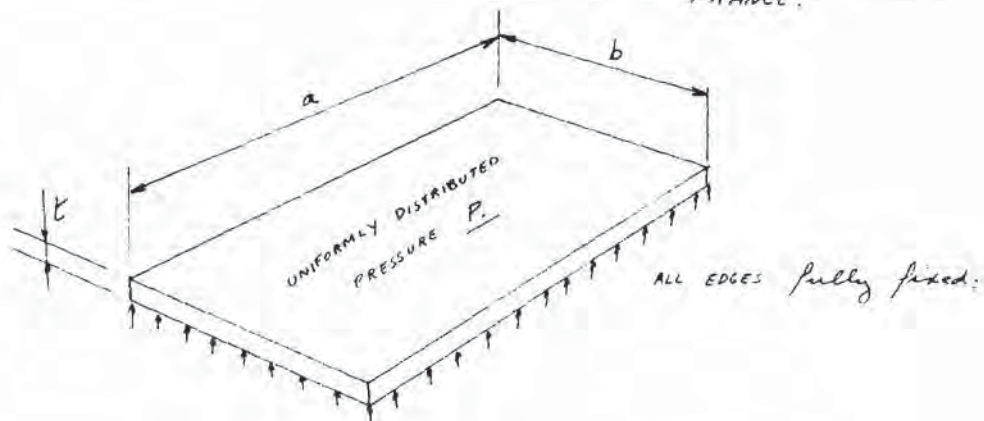
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.FLAT PLATES UNDER TRANSVERSE LOADING.

The following is translated from "RESISTANCE DES MATERIAUX APPLIQUEE A L'AVIATION" BY PAUL VALLAT.

1ST. EDITION - 1944 - PUBLISHED BY: MENARD - EDITIONS

8 RUE DES REGANS - TOULOUSE
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* MAX. BENDING STRESS AT THE EDGES OF THE PLATE:

$$f_{bM} = A P \left(\frac{b}{t} \right)^2$$

MAX. DEFLECTION AT THE CENTER OF THE PLATE:

$$f_M = C \frac{P b}{E(1-\sigma^2)} \left(\frac{b}{t} \right)^3$$

WHERE:

E = Young's modulus.

σ = Poisson's ratio

A = Coef. obtained from curve next page.

C = Coef. obtained from curve next page.

$a, b \& t$ = dimensions of the plate as shown above

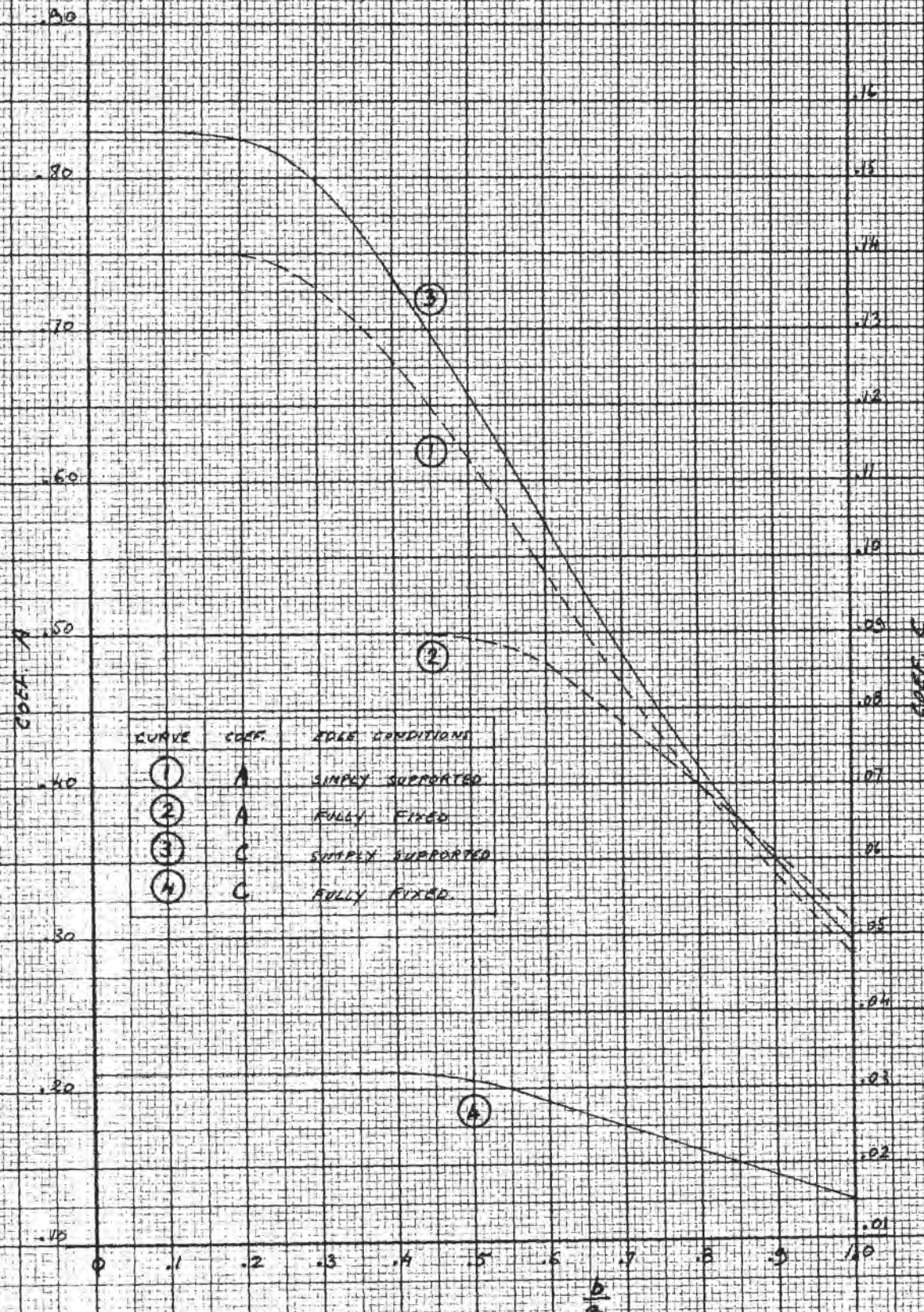
P = applied uniformly distributed pressure.

*: or For simply supported edges: max. bending stress at the center of the plate.

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STRESS ANALYSIS OF 1/8 SCALE HOVERING & TRANSITION MODEL

REF. "RESISTANCE DES MATERIAUX APPLIQUEE A L'AVIATION"
BY P. VALLAT



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10 X 10 TO THE 1/8 INCH
G-15

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL5-0 MODEL STRESS ANALYSIS5-2-2 WING SKIN PANELSATTACHMENT SCREWS.

The skin is held on the ribs by 8 screws
AN-510 #4 or #5.

Screw strength in tension as per specifications:

#5: 396 ^{lb}

#4: 313 ^{lb}

Load per screw with a max pressure force of 556 ^{lb} per panel at a pressure of 17.10 PSI. (unfactored)

$$\frac{556}{8} = 69.5 \text{ } ^{\text{lb}} \text{ unfactored.}$$

Fully factored load per screw: $69.5 \times 4 = 278 \text{ } ^{\text{lb}}$

Considering now a screw at the outer end of the rib and using the higher pressure 18.2 PSI.

Fully factored load per screw:

$$278 \frac{18.2}{17.1} = 296 \text{ } ^{\text{lb}} \text{ (average load)}$$

Considering the drawing, it can be seen that the outer screw will take approximately the pressure on a strip 4" long and 1.3" wide: hence a load: at 72.8 PSI (fully factored)

$$72.8 \times 4 \times 1.3 = \underline{\underline{379 \text{ } ^{\text{lb}}}}$$

∴ #5 screws are required

M.S.

$$\frac{396}{379} - 1 = \underline{\hspace{2cm}}$$

* .068

* NOTE - This Margin of Safety is pessimistic as no account has been taken of the effect of the edge attachment.

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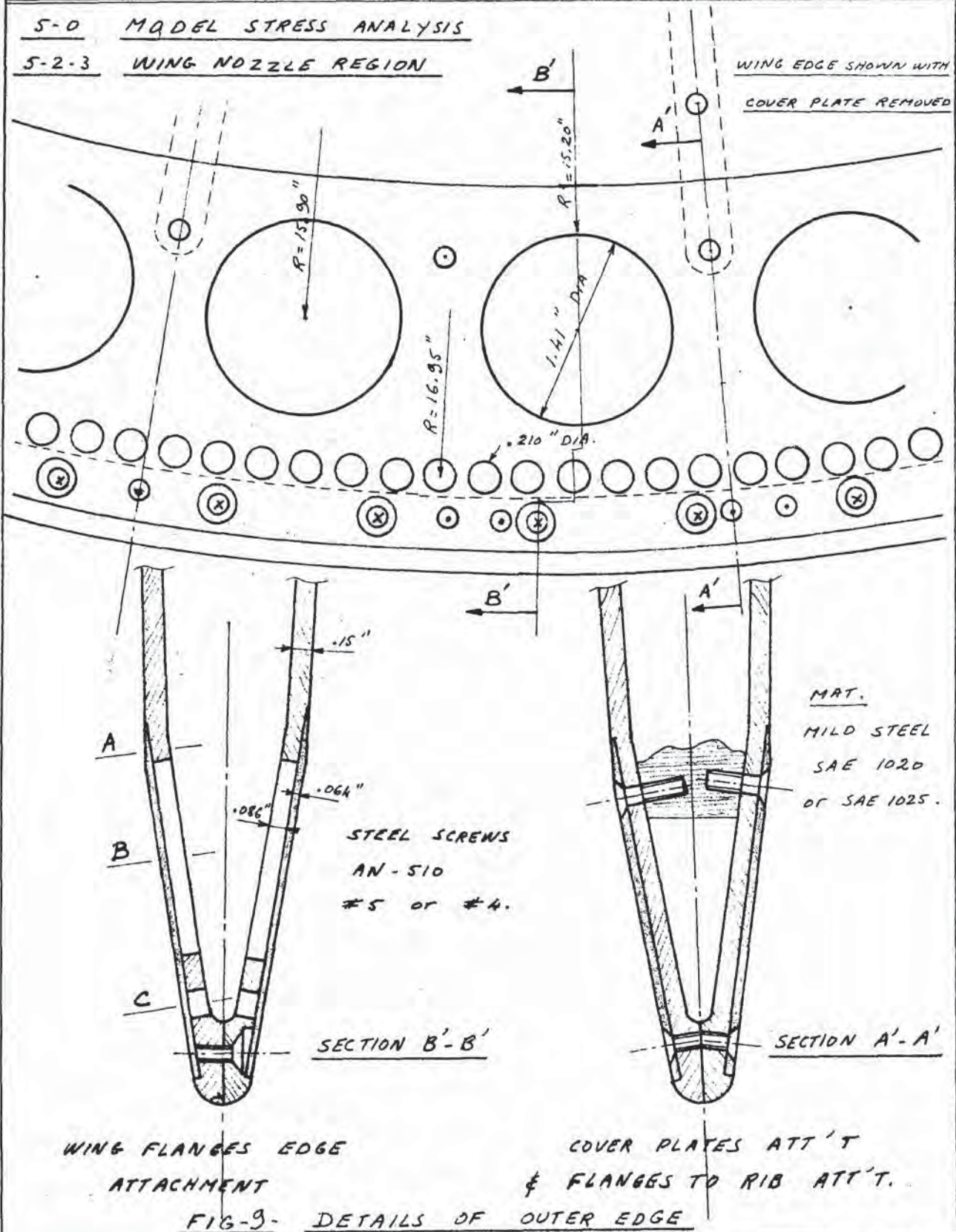
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL-

5-0 MODEL STRESS ANALYSIS

5-2-3 WING NOZZLE REGION



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.5-0 - MODEL STRESS ANALYSIS5-2-3 - WING NOZZLE REGIONASSUMPTIONS FOR STRESSING THE EDGE.

- 1 - The differential pressure will be taken at 18.20 PSI as calculated previously.
- 2 - The edge will be first treated as a rectangular plate .086" thick with all four sides fixed. Size: $a \times b = 4.6" \times 2.0"$
then $\frac{b}{a} = .435$

This assumption can be made since it was found that the deflection at the center of the .15" thick plate would be of the order of .0002" hence negligible. (page 68)

- 3 - The max. stress in bending found from plate theory will be assumed to be constant over the plate for the purpose of stressing the 3 sections A, B & C indicated on the sketch, but will be factored up due to the local reduction in section.
- 4 - Section A will be considered .086" thick.
Section B will be considered as two plates: .086" + .064" working together independently.
Section C will be considered .086" thick.

Note: The .064" plate has to be assumed ineffective near its edges due to insufficient attachment. It is assumed however that enough load can be picked up by the plate to make it effective between the 1.41" holes at section B.

BENDING STRESS IN THE PLATE AS PER ASSUMPTIONS ① & ②

$$f_b = AP \left(\frac{b}{t} \right)^2 = .49 \times 18.20 \left(\frac{2.0}{.086} \right)^2 = 4830 \text{ PSI}$$

$$A = .49 \quad (\text{from } ②)$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

5-0 MODEL STRESS ANALYSIS

5-2-3 WING NOZZLE REGION

STRESSING OF THE EDGE.

SECTION B.

Basic section in bending will be assumed to be a 15° arc of radius 15.90"

i.e. 4.16" long, having a section modulus:

$$\frac{4.16}{f} \cdot 0.86^2 = .00512 \text{ in}^3$$

The actual section is made of $(1.34" \times .086") + (1.34" \times .064")$
 having a section modulus $\frac{1.34}{6} (.086^2 + .064^2) = .00257 \text{ in}^3$

having a section modulus: $\frac{1.34}{6} (.086^2 + .064^2) = .00257 \text{ in}^3$

Hence, the bending stress:

$$4830 \frac{.00512}{.00257} = 9640 \text{ PSI @ } 55000$$

fully factored: $9640 \times 4 = 38600$ PSI ^{.00257} M.S: $\frac{55000}{38600} - 1 = \underline{\hspace{2cm}}$.425

SECTION C -

Basic section in bending will be assumed to be a 15° arc of radius $16.95''$ i.e. $4.43''$ long. Having a section modulus:

$$\frac{4.43}{6} \cdot .086^2 = .00545 \text{ in}^3$$

$$\frac{4.43}{6} \cdot .086^2 = .00545 \text{ in}^3$$

The actual section has only $1.49" \times .086"$

the actual section has only 1.49 x .086
having a section modulus: $\frac{1.49}{6} \cdot .086^2 = .001832 \text{ in}^3$

Hence, the bending stress:

$$4830 \frac{.00545}{.001832} = 14400 \text{ PSI @ } 55000.$$

fully factored : $14400 \times 4 = 57600 \text{ PSI}$

M.S: $\frac{55000}{57600} - 1 = \text{---} - .0h$

ACTUAL MARGIN OF SAFETY ON
APPLIED LOAD

3.95:

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL5-0 MODEL STRESS ANALYSIS5-2-4 WING EDGE ATTACHMENT.STRESSING OF THE EDGE.ATTACHMENT SCREWS.

Strength in tension of #5-44 & #4-48 - AN-510 SCREWS per turn of thread.

Screw strength in tension as given by AN-510 - Specs.

#5 - 396^{lb}

for fully engaged threads.

#4 - 313^{lb}

This strength is based on threads engaged in a standard nut - min height of nut and nb of turns of thread:

#5-44 : $h = .102" - .114"$ $n = 4.48$

#4-48 : $h = .087" - .098"$ $n = 4.17$

Strength per turn of thread:

#5-44 : $\frac{396}{4.48} = 88.4^{lb}$

#4-48 : $\frac{313}{4.17} = 75.0^{lb}$

SCREWS ATTACHING WING FLANGES AT THE EDGE.

- Length of thread engaged $\approx .15" > .102"$ hence full strength available.
- Each screw can be considered as taking a maximum load equal to the pressure over 2 in^2 : $18.2 \times 2 = 36.4^{lb}$

if n^6 H screws are used:

$$M.S : \frac{313}{4 \times 36.4} - 1 = \underline{\hspace{2cm}} \quad 1.15$$

" " 5 " " " :

$$M.S : \frac{396}{4 \times 36.4} - 1 = \underline{\hspace{2cm}} \quad 1.72$$

SCREWS ATTACHING THE COVER PLATES.

- Length of thread engaged : $.086"$ i.e. nb of thread engaged:

#5 : 3.78 available strength : $88.4 \times 3.78 = 334^{lb}$

#4 : 4.13 " " : $75 \times 4.13 = 310^{lb}$

- Assuming again 2 in^2 pressure as a max load : 36.4^{lb} per screw.

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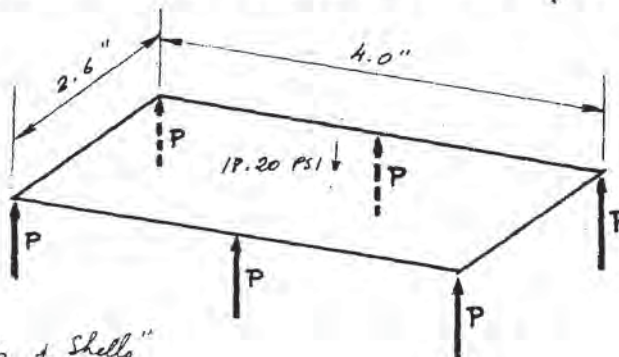
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL5-0 MODEL STRESS ANALYSIS5-2-5 - WING .064" COVER PLATES
ATTACHMENT SCREWS CONT'D.SCREWS ATTACHING THE COVER PLATES - CONT'D

| | | | |
|---------------------------|------|-----------------------------------|------|
| if $N=4$ screws are used: | M.S. | $\frac{310}{4 \times 36.4} - 1 =$ | 1.1. |
| " " 5 " " " : | M.S. | $\frac{334}{4 \times 36.4} - 1 =$ | 1.2 |

.064 COVER PLATE -

This plate will be covered for the case where it is used to blank the 2 sets of holes. Due to splines every other ribs; it must be considered as a plate under uniform loading supported at 6 points. The max pressure of 18.2 PSI will be considered over the plate.



Using Timoshenko "Plates & Shells"

page 243

Ratio $\frac{b}{a} = \frac{2.6}{4.0} = 1.3$ hence: $\alpha = .0423$

$\beta = .0210$

$\beta_1 = .0385$

Deflection at center of plate:

$$w = \alpha \frac{q b^4}{E h^3} = .0423 \frac{18.2 \times 2.6^4}{30 \times 10^6 \times .064^3} = .00446''$$

$$M_x = \beta q b^2 = .0210 \times 18.2 \times 2.6^2 = 2.585 \text{ in} \cdot \text{lb}$$

$$M_y = \beta_1 q b^2 = .0385 \times 18.2 \times 2.6^2 = 4.730 \text{ in} \cdot \text{lb}$$

$$\sqrt{M_x^2 + M_y^2} = \sqrt{2.585^2 + 4.73^2} = 5.32 \text{ in} \cdot \text{lb}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL5-0 MODEL STRESS ANALYSIS5-2-5 WING .064" COVER PLATE.064 COVER PLATE - CONT'D.

Section modulus of .064" x 1.00" of plate:

$$\frac{1 \times .064^2}{6} = .000684 \text{ in}^3$$

Max Bending stress in the plate: $\frac{5.32}{.000684} = 7800 \text{ PSI} \text{ @ } 55000$ fully factored: $7800 \times 4 = 31200 \text{ PSI}$

M.S.

$$\frac{55000}{31200} - 1 =$$

.765

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -5-0 MODEL STRESS ANALYSIS5-2-6 WING - MAX. PRESSURE PERMISSIBLE-PRESSURE REQUIRED TO PRODUCE STRUCTURAL FAILURE OF THE WING.

The weakest point of the wing is section C of the edge with a margin of safety : $-.048$ and a load factor $n = 4$.

$$\text{Hence, the failing pressure : } 4 \times 18.20 \times (1 - .048) = \underline{\underline{69.4 \text{ PSI}}}$$

$$\text{Pressure at yield of the material : } 69.4 \times \frac{36}{55} = \underline{\underline{45.3 \text{ PSI}}}$$

PRESSURE REQUIRED TO PRODUCE FAILURE OF THE .064" COVER PLATE.

The minimum margin of safety on the cover plate is : $+.762$

$$\text{Hence the failing pressure : } 4 \times 18.20 (1 + .762) = \underline{\underline{128 \text{ PSI}}}$$

$$\text{Pressure at yield of the material : } 128 \times \frac{36}{55} = \underline{\underline{83.7 \text{ PSI}}}$$

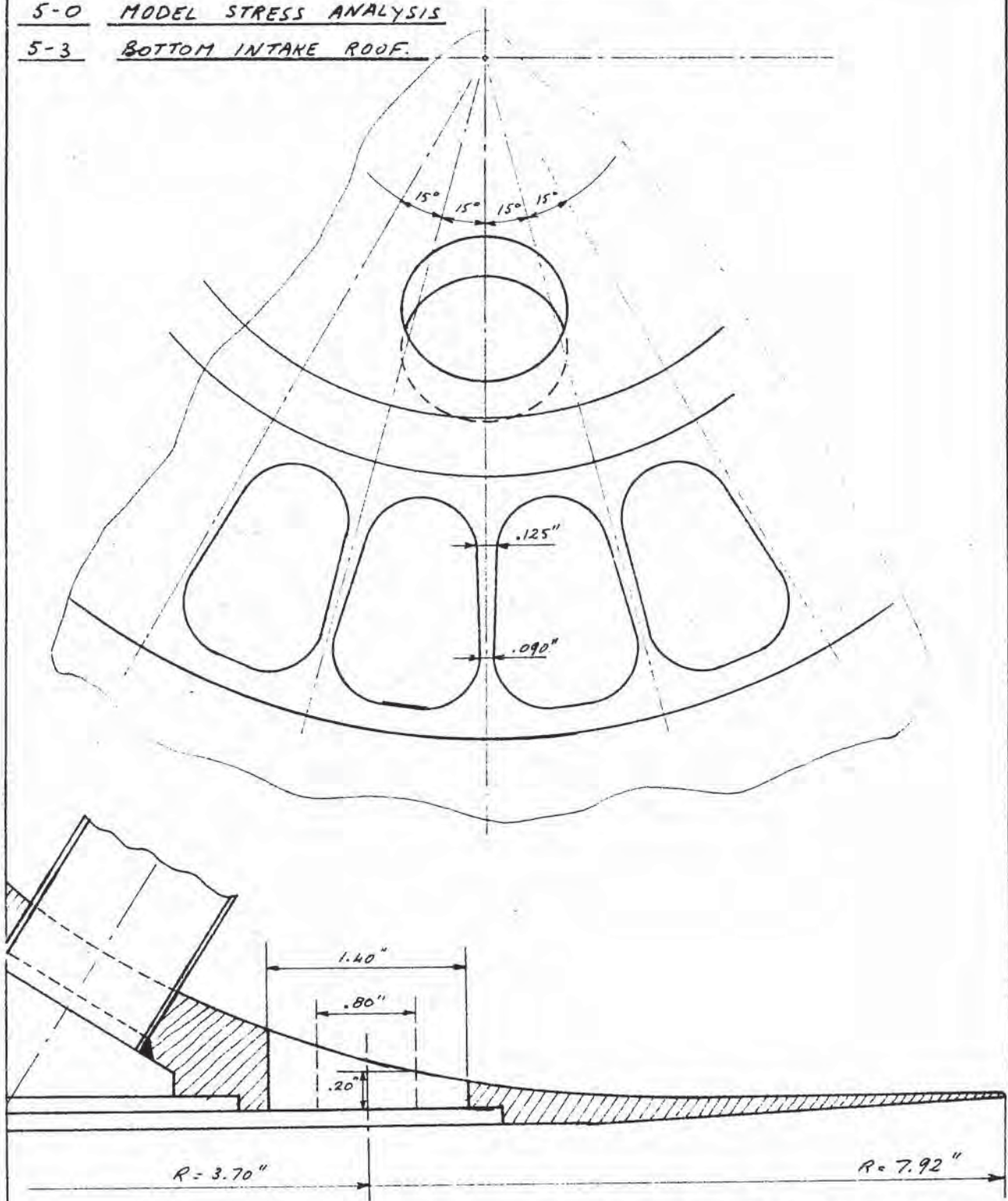
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.5-0 MODEL STRESS ANALYSIS5-3 BOTTOM INTAKE ROOF.

MAX. DIFFERENTIAL PRESSURE : ESTIMATED : 1 PSI.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.5-0 MODEL STRESS ANALYSIS5-3 BOTTOM INTAKE ROOF5-3-1 INLET SPOKES.

Each spoke will be considered as taking the load applied on a 15° segment of annulus of radius: 7.92" & 3.70". Since the rigidity of the annulus is much larger than that of the spokes, the spokes will be working as cantilever beams having their free end fixed against rotation.

Area of annulus intersecting each spoke:
 $\pi (7.92^2 - 3.7^2) \frac{15}{360} = 6.41 \text{ in}^2$

Nett load per spoke: fully factored - estimated differential pressure:
 1 PSI

$$6.41 \times 1 \times 4 = 25.65 \text{ lb}$$

The smallest section of the spoke .20" x .09" will be assumed constant along the .80" length:

$$\frac{P}{B} = \frac{M}{Z} = \frac{\frac{PL}{2}}{\frac{bh^2}{6}} = 3 \frac{PL}{bh^2} = 3 \frac{25.65 \times .80}{.09 \times .20^2} = \frac{61.5}{.0036} = 17100 \text{ PSI}$$

$$\text{M.S. } \frac{55000}{17100} - 1 = \text{---} = 2.22$$

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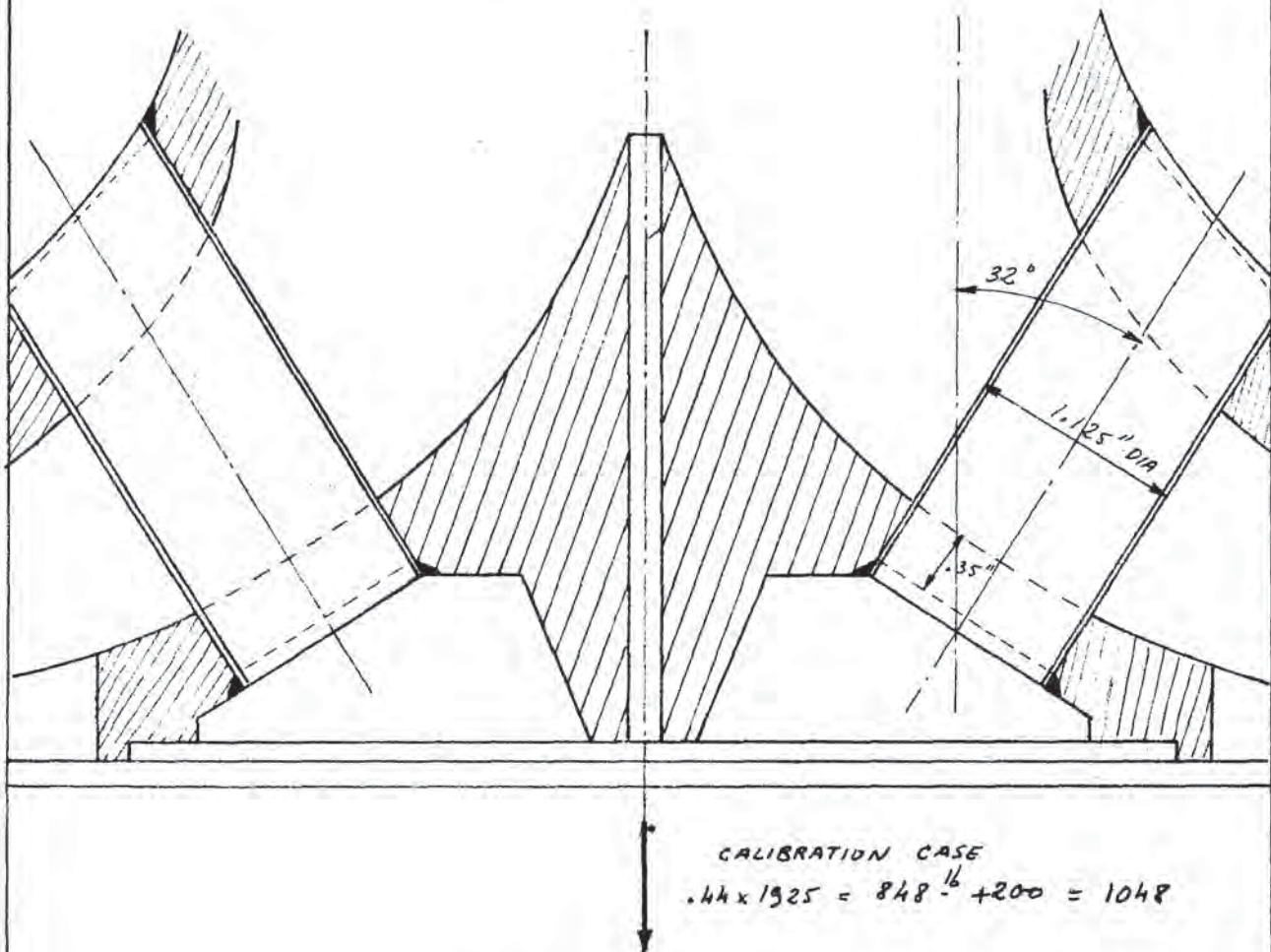
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELS-0 MODEL STRESS ANALYSISS-3 BOTTOM INTAKE ROOFS-3-2 EXHAUST TUBES ATTACHMENT.

CALIBRATION CASE
 $.44 \times 1925 = 848 \frac{1}{2} + 200 = 1048$

The max. loads on this attachment will occur in the calibration case from section 10 under the max down load of $1925 \frac{1}{2}$.
 44% of this down load is taken by the rod: $1048 \frac{1}{2}$

Hence: load per tube fully factored: $1048 \frac{1}{2} \times \frac{4}{6} = 698 \frac{1}{2}$

Area of solder in shear: $1.125 \times \pi \times .35 = 1.238 \text{ in}^2$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL5-0 MODEL STRESS ANALYSIS5-3 BOTTOM INTAKE ROOF5-3-2 EXHAUST TUBES ATTACHMENT.

Axial load on each tube: $\frac{698}{\cos 32^\circ} = 824 \text{ lb}$

Shear stress on the solder: $\frac{824}{1.238} = 665 \text{ PSI}$

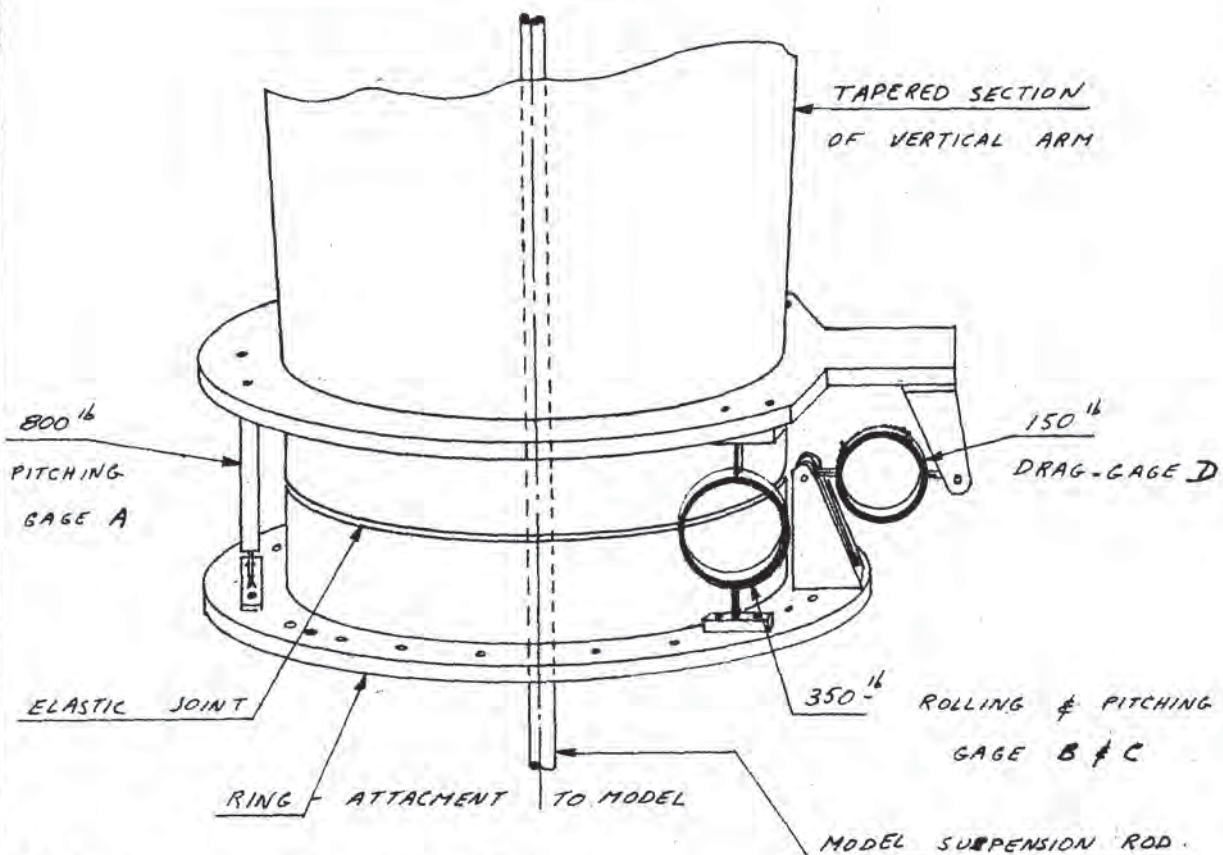
The solder used is a 95% tin - 5% lead type

Ref: AP-370 - CHAPT. 405-3 -18 ultimate shear strength
of solder: 4000 PSI.

M.S: $\frac{4000}{665} - 1 = \text{-----} 5.00$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL6-0 LOAD GAGE DESIGN.6-1 LOAD ANALYSIS.6-1-1 LOADING CONSIDERATIONSDESCRIPTION OF GAGE SECTIONFIG-10 GAGE SECTION

The model is attached at the bottom of the vertical arm by means of a vertical steel rod and four rings load measuring gages as shown above.

The suspension rod is used to support the model in such a way that no load due to model weight is registered by the gages when the arm is vertical.

Gages A, B & C will measure both pitching moments and loads normal to the plane of the model. In addition, gages B & C

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -

| | |
|--------------|-------------------------------|
| <u>6-0</u> | <u>LOAD GAGE DESIGN</u> |
| <u>6-1</u> | <u>LOAD ANALYSIS</u> |
| <u>6-1-1</u> | <u>LOADING CONSIDERATIONS</u> |

DESCRIPTION OF GAGE SECTION - CONT'D

will measure rolling moments. Gage D will measure loads parallel to the plane of the model.

No gage has been provided for measurement of side load.

LOAD PATHS THROUGH GAGE SECTION -

The loads resolved at the model center consist of three forces: Vertical, fore/aft and side and two moments: pitching and rolling. Due to symmetry around the vertical axis, no yawing moment can be produced.

Due to the offset between model center and gage center, the gages will have the following response to the case of fore/aft and side load:

- a/ Fore/aft load: Gage D will indicate a pull or a push. Gages A, B & C a pitching moment.
- b/ Side load: Gages B & C will indicate a rolling moment.

Side forces will be taken as side loads on gages AB & C which are designed to resist them without affecting their normal load measuring accuracy.

The gage center in the case of fore/aft load is obviously contained in a horizontal plane passing through the drag gage D. In the case of side load, it must be in a

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

- 6-0 LOAD GAGE DESIGN
6-1 LOAD ANALYSIS
6-1-1 LOADING CONSIDERATIONS -

LOAD PATHS THROUGH GAGE SECTION - CONT'D

plane passing by the points of zero bending in gages A, B & C operating as cantilever beams with the free end guided against rotation. Since the point of zero bending of gages A, B & C is at the mid distance between the two flanges and since gage D is also placed at mid distance between the same two flanges, the two planes are coincident. The gage center under vertical loads lies on the vertical axis. Hence, the center of all gages is at the intersection of the vertical axis and the plane defined above.

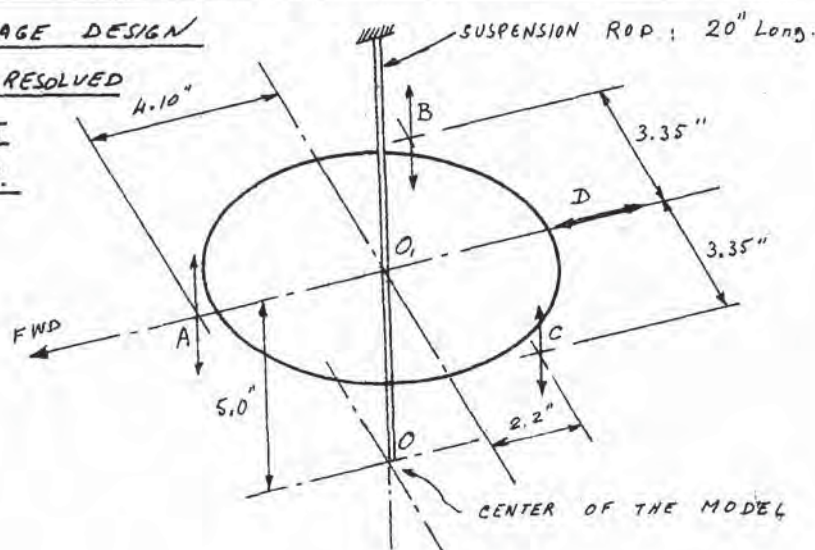
NOTE.

At the time this section of the report was written, the geometry of the gage section was as shown on 6-1-2. Later on, this geometry has been slightly modified to the dimensions shown in 6-3. Since this modification does not materially alter the gage loading, the section has not been rewritten.

However, should exact values of the loads on the gages be needed, they can be computed easily from the equations given in 6-3.

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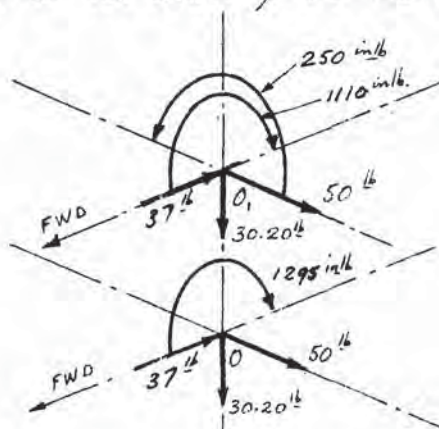
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL-6-0 - LOAD GAGE DESIGN6-1-2 - LOADS RESOLVEDAT GAGE
CENTER.LOADS RESOLVED AT POINT O,

A 50 lb side load is assumed acting at the center of the model

+ 20° CASE -

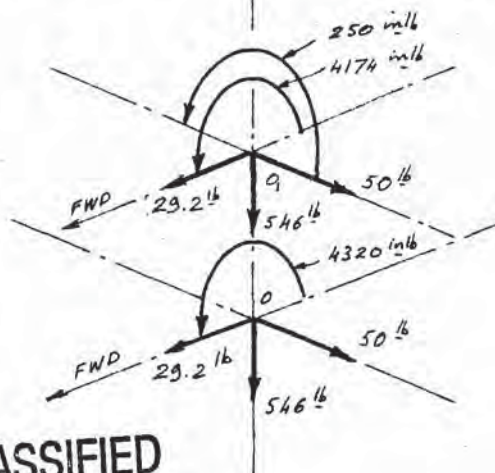
$$M_L = 1295 - (37 \times 5.0) = 1110 \text{ in/lb}$$

$$M_T = 50 \times 5.0 = 250 \text{ in/lb}$$

- 10° CASE

$$M_L = 4320 - (29.2 \times 5.0) = 4174 \text{ in/lb}$$

$$M_T = 50 \times 5.0 = 250 \text{ in/lb}$$



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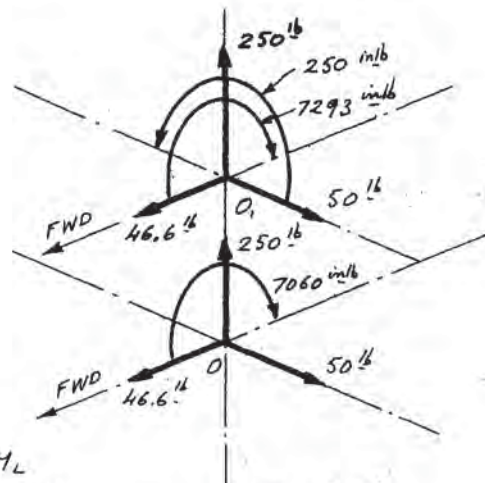
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL6-0 LOAD GAGE DESIGN6-1-2 LOADS RESOLVED AT GAGE CENTER.+ 45° CASE - TUNNEL AT $q = 30$ PSF

$$M_L = 7060 + (46.6 \times 5.0) = 7293 \text{ in/lb}$$

$$M_T = 50 \times 5.0 = 250 \text{ in/lb}$$



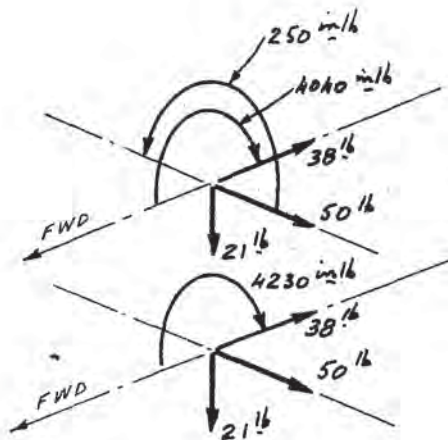
Value of q required to reduce the moment M_L to 4200 in/lb in order not to exceed the strength requirements of the range of $-10^\circ < \alpha < 20^\circ$.

$$q_{45} = 30 \frac{4200}{7300} = 17.25. \quad \text{SAY } 18 \text{ PSF}$$

+ 45° CASE - TUNNEL AT $q = 18$ PSF.

$$M_L = 4230 - (38 \times 5) = 4040 \text{ in/lb}$$

$$M_T = 50 \times 5.0 = 250 \text{ in/lb}$$



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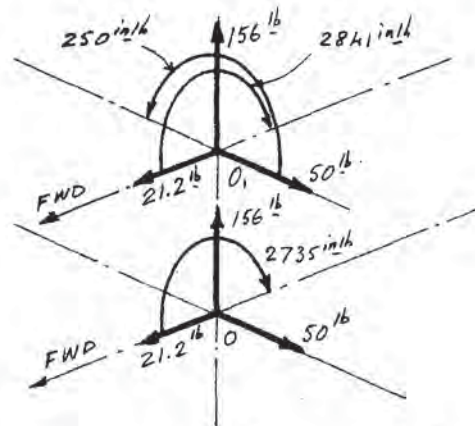
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL6-0 LOAD GAGE DESIGN6-1-2 LOADS RESOLVED AT GAGE CENTER.+35° CASE- $q = 30 \text{ PSF}$

$$M_L = 2735 + (21.2 \times 5) = 2841 \text{ in/lb}$$

$$M_T = 50 \times 5.0 = 250 \text{ in/lb}$$



In this case, the moment is considerably smaller than 4200 in/lb hence the tunnel can be operated at $q = 30 \text{ PSF}$.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL6-1-3 - LOAD DISTRIBUTIONDISTRIBUTION OF A NORMAL LOAD ON GAGES A, B & C.DISTRIBUTION OF A SIDE LOAD ON GAGES A, B & C.LOAD ON GAGE A:

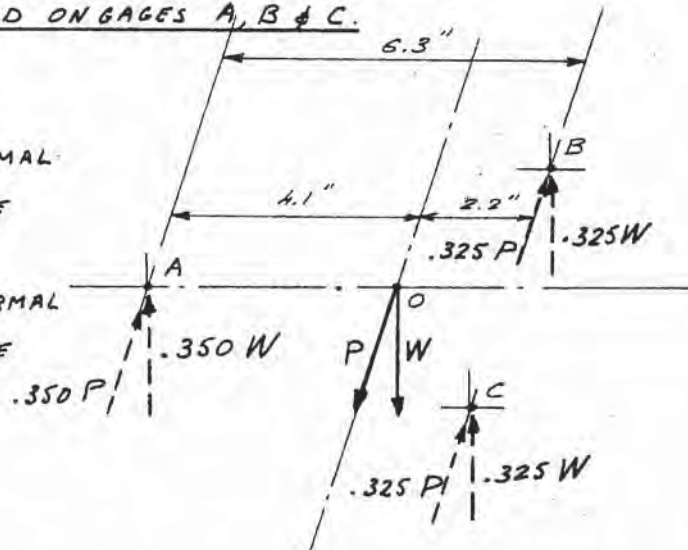
$$W \frac{2.2}{6.3} = .350 W \quad \text{NORMAL}$$

$$P \frac{2.2}{6.3} = .350 P \quad \text{SIDE}$$

LOAD ON GAGES B & C:

$$W \frac{4.1}{6.3 \times 2} = .325 W \quad \text{NORMAL}$$

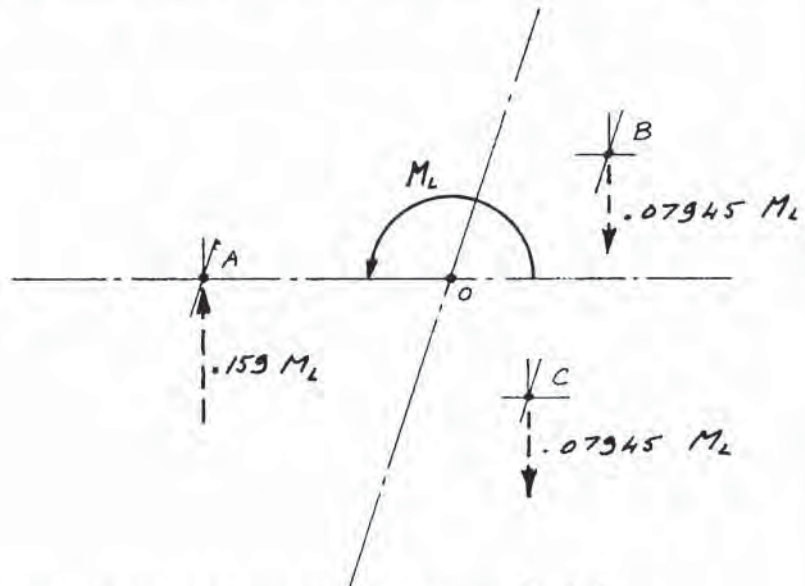
$$P \frac{4.1}{6.3 \times 2} = .325 P \quad \text{SIDE}$$

DISTRIBUTION OF A LONGITUDINAL MOMENT ON GAGES A, B & C.LOAD ON GAGE A.

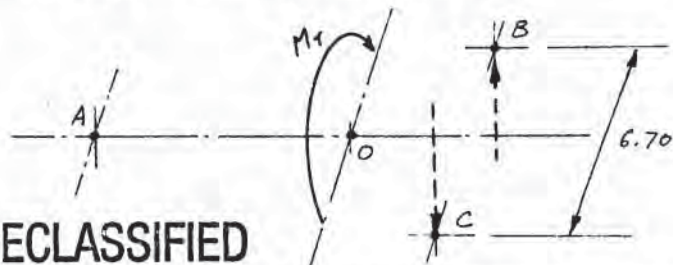
$$\frac{M_L}{6.3} = .159 M_L$$

LOAD ON GAGES B & C

$$\frac{-M_L}{2 \times 6.3} = -.07945 M_L$$

DISTRIBUTION OF A TRANSVERSAL MOMENT ON GAGES B & CLOADS ON GAGES B & C

$$\frac{M_T}{6.7} = \pm .1492 M_T$$



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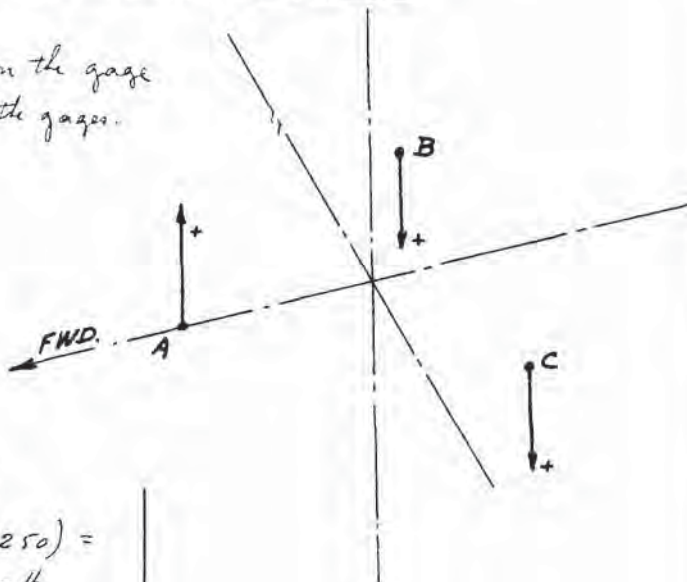
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -6-1-3 LOAD DISTRIBUTION -LOADS ON THE GAGES - EFFECT OF MOMENTS ONLY -

+ve load on gage A: compression on the gage
 +ve " " " B & C: tension on the gages.

-10° CASE -

GAGE:

$$A : -.159 \times 4174 = -664.16$$

$$B : (-.07945 \times 4174) + (.1492 \times 250) = -332 + 37.3 = 294.716$$

$$C : (-.07945 \times 4174) - (.1492 \times 250) = -332 - 37.3 = 369.316$$

+20° CASE -

GAGE:

$$A : -.159 \times 1110 = -176.516$$

$$B : (.07945 \times 1110) + (.1492 \times 250) = 88.0 + 37.3 = 125.316$$

$$C : (.07945 \times 1110) - (.1492 \times 250) = 88.0 - 37.3 = 50.716$$

+45° - 189 - CASE.

GAGE:

$$A : .159 \times 4040 = 643.16$$

$$B : (.07945 \times 4040) + (.1492 \times 250) = 321.5 + 37.3 = 358.816$$

$$C : (.07945 \times 4040) - (.1492 \times 250) = 321.5 - 37.3 = 284.216$$

SUMMARY OF GAGE LOADS
EFFECT OF MOMENTS ONLY.

| CASE: | -10° | +20° | +45° |
|----------|------------|------------|-----------|
| Tunnel 4 | 30 | 30 | 18 |
| GAGE A | 664.16 T | -176.516 C | 643.16 C |
| GAGE B | -294.716 C | 125.316 T | 358.816 T |
| GAGE C | -369.316 C | 50.716 T | 284.216 T |

REQUIRED GAGE RATING.

$$A : 80016$$

$$B : 35016$$

$$C : 35016$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL6-1-3 LOAD DISTRIBUTIONSUSPENSION ROD.

The rod is designed at an operating stress of 20000 PSI. to take a max. load of 550 lb

$$\text{Required diameter: } \sqrt{\frac{4}{\pi} \frac{W}{f}} = D$$

$$D = \sqrt{\frac{4}{\pi} \frac{550}{20000}} = \sqrt{.035} = .187"$$

$$\text{Sectional area: } .187^2 \frac{\pi}{4} = .0275 \text{ in}^2$$

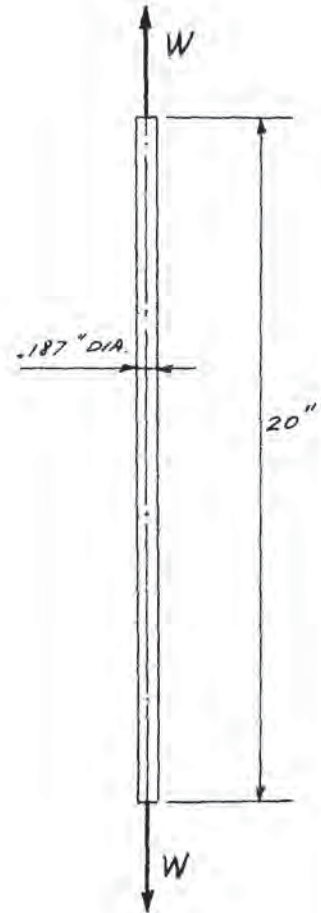
$$\text{ELONGATION: } \delta = \frac{WL}{AE}$$

MAT: SAE - 4130 - CHR. MOLY - STEEL.

@ 125000 PSI UTS.

ELONGATION PER POUND LOAD.

$$\delta = W \frac{20}{.0275 \times 20 \times 10^6} = 2.42 \times 10^{-5} W \text{ in/lb}$$



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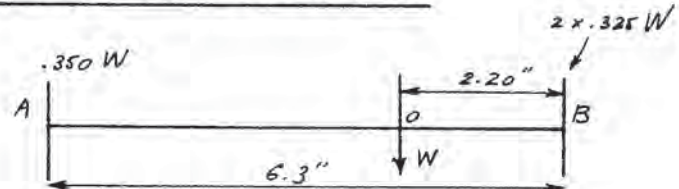
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -E-1-3 LOAD DISTRIBUTION -DISTRIBUTION OF LOAD BETWEEN GAGES AND CENTER ROD.

Deflection rate:

Gage A : $2.66 \times 10^{-5} \frac{\text{in}}{\text{lb}}$

Gage B : $7.42 \times 10^{-5} \frac{\text{in}}{\text{lb}}$



For a unit gage load.

Deflection at A : $.35 \times 2.66 \times 10^{-5} = .93 \times 10^{-5} \frac{\text{in}}{\text{lb}}$

Deflection at B : $.325 \times 7.42 \times 10^{-5} = 2.415 \times 10^{-5} \frac{\text{in}}{\text{lb}}$

Then: deflection at O:

$$\left[2.415 - (.93) \frac{2.2}{6.3} \right] \times 10^{-5} = 1.895 \times 10^{-5} \frac{\text{in}}{\text{lb}}$$

Deflection rate of the rod: $2.42 \times 10^{-5} \frac{\text{in}}{\text{lb}}$

Now, let W_1 & δ_1 be the load and deflection of the rodand W_2 & δ_2 be the load and deflection of the gage system at point O
and ΔW the incremental load on the system.Then, we must have: $\Delta W = W_1 + W_2$ and $\delta_1 = \delta_2$ Let $\Delta W = 1$ and calculate a relation between W_1 & W_2

we have: $\delta_1 = 2.42 \times 10^{-5} W_1$

$\delta_2 = 1.895 \times 10^{-5} W_2$

$\therefore 2.42 \times 10^{-5} W_1 = 1.895 \times 10^{-5} W_2$

$$W_2 = \frac{2.42}{1.895} W_1 = 1.278 W_1$$

Hence: $\Delta W = W_1 + 1.278 W_1 = 2.278 W_1 = 1$

$$\text{then: } W_1 = \frac{1}{2.278} = .44 \quad ; \quad \text{The rod takes } 44\% \text{ of } W$$

$$\text{the gages } 56\% \text{ of } W.$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELG-1-3 LOAD DISTRIBUTION -DISTRIBUTION OF LOAD BETWEEN GAGES & CENTER ROD - cont'd.

From Page : 89 the load on gage A has been found to be 35% of the total load on the gage system and 32.5 % on gage B & C respectively.

Hence: in terms of the incremental load ΔW .

$$\text{Load on gage A: } .56 \times .35 = .196 = 19.6 \%$$

$$\text{Load on gage B or C: } .56 \times .325 = .182 = 18.2 \%$$

Hence: The load distribution is:

| ROD | GAGE A | GAGE B | GAGE C |
|------|--------|--------|--------|
| 44 % | 19.6 % | 18.2 % | 18.2 % |

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL6-1.3 LOAD DISTRIBUTIONLOAD ON THE GAGES WITH THE ROD ADJUSTED TO TAKE 200 $\frac{1}{16}$.SUCTION ON-10° CASE - g = 30 PSF

| LOAD | | ROD | A | B | C |
|------------------|----------------------|----------|----------|----------|----------|
| | | 44% | 19.6% | 18.2% | 18.2% |
| MODEL WEIGHT. | 200 $\frac{1}{16}$ | 200 ↓ | 0 | 0 | 0 |
| NORMAL COMP. 197 | - 3 $\frac{1}{16}$ | - 1.32 ↑ | - .588 ↑ | - .546 ↑ | - .546 ↑ |
| PRESSURE | 286 $\frac{1}{16}$ | 126 ↓ | 56 ↓ | 52 ↓ | 52 ↓ |
| AIRLOAD | 68.13 $\frac{1}{16}$ | 27.8 ↓ | 12.4 ↓ | 11.5 ↓ | 11.5 ↓ |
| MOMENTS | | 0 | 664 ↓ | - 295 ↑ | - 369 ↑ |
| | | 352.48 ↓ | 731.8 ↓ | 232.1 ↑ | 306.1 ↑ |

+ 20° CASE - g = 30 PSF.

| LOAD | | ROD | A | B | C |
|------------------|--------------------|-----------|------------|-----------|-----------|
| | | 44% | 19.6% | 18.2% | 18.2% |
| MODEL WEIGHT | 200 $\frac{1}{16}$ | 200 ↓ | 0 | 0 | 0 |
| NORMAL COMP. 188 | - 12 | - 5.28 ↑ | - 2.35 ↑ | - 2.185 ↑ | - 2.185 ↑ |
| PRESSURE | 286 | 126 ↓ | 56 ↓ | 52 ↓ | 52 ↓ |
| AIRLOAD | - 443.8 | - 195.2 ↑ | - 87.0 ↑ | - 80.8 ↑ | - 80.8 ↑ |
| MOMENTS | | 0 | 222.5 ↑ | 148.55 ↓ | 74 ↓ |
| | | 145.52 ↓ | - 255.85 ↑ | 117.565 ↓ | 43.015 ↓ |

NOTE. Airload + pressure load + normal component of model weight =
net normal load given page 40.

Load given above under normal component is the change in normal
load due to model weight with angle of attack.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MONEY6-1-3 LOAD DISTRIBUTION -LOAD ON THE GAGES WITH THE ROD ADJUSTED TO TAKE 200 lb.SUCTION ON+45° CASE - $q = 18$ PSF

| LOAD | | ROD | A | B | C |
|------------------|--------------------|----------|----------|----------|----------|
| | | 44% | 19.6% | 18.2% | 18.2% |
| MODEL WEIGHT | 200 ^{lb} | 200 ↓ | 0 | 0 | 0 |
| NORMAL COMP. 141 | -59 ^{lb} | -26 ↑ | -11.56 ↑ | -10.72 ↑ | -10.72 ↑ |
| PRESSURE | 286 ^{lb} | 126 ↓ | 56 ↓ | 52 ↓ | 52 ↓ |
| AIRLOAD | -406 ^{lb} | -178.9 ↑ | -79.5 ↑ | -73.8 ↑ | -73.8 ↑ |
| MOMENTS | | 0 | -643 ↑ | 359 ↓ | 284 ↓ |
| | | 121.1 ↓ | 678.06 ↑ | 326.48 ↓ | 251.48 ↓ |

SUCTION OFF.-10° CASE - $q = 30$ PSF

| LOAD | | ROD | A | B | C |
|------------------|-------------------|----------|-----------|-----------|-----------|
| | | 44% | 19.6% | 18.2% | 18.2% |
| MODEL WEIGHT | 200 ^{lb} | 200 ↓ | 0 | 0 | 0 |
| NORMAL COMP. 197 | -3 ^{lb} | -1.32 ↑ | -588 ↑ | -546 ↑ | -546 ↑ |
| PRESSURE * | 320 | 141 ↓ | 62.6 ↓ | 58.2 ↓ | 58.2 ↓ |
| AIRLOAD | 63.13 | 27.8 ↓ | 12.4 ↓ | 11.5 ↓ | 11.5 ↓ |
| MOMENTS | | | 664 ↓ | 295 ↑ | 369 ↑ |
| | | 367.48 ↓ | 718.412 ↓ | -225.85 ↑ | -299.85 ↑ |

* SEE PAGE 20

SEE NOTE PAGE 94

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -6-1-3 LOAD DISTRIBUTIONLOAD ON THE GAGES WITH THE ROD ADJUSTED TO TAKE 200 $\frac{1}{16}$ SUCTION OFF -+ 20° CASE - g = 30 PSF

| LOAD | | ROD | A | B | C |
|------------------|-----------------------|----------|-----------|-----------|----------|
| | | 44% | 19.6% | 18.2% | 18.2% |
| MODEL WEIGHT | 200 $\frac{1}{16}$ | 200 ↓ | 0 | 0 | 0 |
| NORMAL COMP. 188 | -12 $\frac{1}{16}$ | -5.28 ↑ | -2.35 ↑ | -2.185 ↑ | -2.185 ↑ |
| PRESSURE * | 320 $\frac{1}{16}$ | 141 ↓ | 62.6 ↓ | 58.2 ↓ | 58.2 ↓ |
| AIRLOAD | -443.8 $\frac{1}{16}$ | -195.2 ↑ | -87.0 ↑ | -80.8 ↑ | -80.8 ↑ |
| MOMENTS | | 0 | 222.5 ↑ | 148.55 ↓ | 74 ↓ |
| | | 140.52 ↓ | -249.25 ↑ | 223.765 ↓ | 49.215 ↓ |

+ 45° CASE - g = 18 PSF

| LOAD | | ROD | A | B | C |
|-----------------|---------------------|----------|-----------|----------|----------|
| | | 44% | 19.6% | 18.2% | 18.2% |
| MODEL WEIGHT | 200 $\frac{1}{16}$ | 200 ↓ | 0 | 0 | 0 |
| NORMAL COMP 141 | -59 $\frac{1}{16}$ | -26 ↑ | -11.55 ↑ | -10.72 ↑ | -10.72 ↑ |
| PRESSURE * | 320 $\frac{1}{16}$ | 141 ↓ | 62.6 ↓ | 58.2 ↓ | 58.2 ↓ |
| AIRLOAD | -406 $\frac{1}{16}$ | -178.5 ↑ | -79.5 ↑ | -73.8 ↑ | -73.8 ↑ |
| MOMENTS | | 0 | -643 ↑ | 359 ↓ | 284 ↓ |
| | | 136.5 ↓ | -671.45 ↑ | 332.68 ↓ | 257.68 ↓ |

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SECRET DECLASSIFIEDSTRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL6-1-3 - LOAD DISTRIBUTION -LOAD ON THE GAGES WITH THE ROD DISCONNECTED.SUCTION ON.-10° CASE - $q = 30 \text{ PSF}$

| LOAD | | ROD | A | B | C |
|--------------|-------|-----|---------|-----------|-----------|
| | | 0 % | 35 % | 32.5 % | 32.5 % |
| WEIGHT COMP. | 197 | 0 | 69 ↓ | 64 ↓ | 64 ↓ |
| PRESSURE * | 286 | 0 | 100 ↓ | 93 ↓ | 93 ↓ |
| AIRLOAD | 63.13 | 0 | 22.1 ↓ | 20.5 ↓ | 20.5 ↓ |
| MOMENTS | | 0 | 664 ↓ | - 295 ↑ | - 369 ↑ |
| | | 0 | 855.1 ↓ | - 117.5 ↑ | - 191.5 ↑ |

+ 20° CASE - $q = 30 \text{ PSF}$

| LOAD | | ROD | A | B | C |
|--------------|-------------------|-----|-----------|-----------|-----------|
| | | 0 % | 35 % | 32.5 % | 32.5 % |
| WEIGHT COMP. | 188 ¹⁴ | 0 | 65.8 ↓ | 61.1 ↓ | 61.1 ↓ |
| PRESSURE * | 286 | 0 | 100 ↓ | 93 ↓ | 93 ↓ |
| AIRLOAD | -4.38 | 0 | - 155.4 ↑ | - 144.2 ↑ | - 144.2 ↑ |
| MOMENTS | | 0 | - 222.5 ↑ | 148.55 ↓ | 74 ↓ |
| | | 0 | - 212.1 ↑ | 158.4 ↓ | 83.9 ↓ |

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL6-1-3 LOAD DISTRIBUTIONLOAD ON THE GAGES WITH THE ROD DISCONNECTED.SUCTION ON+45° CASE - $\bar{z} = 18$ PSF

| LOAD | | ROD | A | B | C |
|--------------|------|-----|----------|---------|---------|
| | | 0% | 35% | 32.5% | 32.5% |
| WEIGHT COMP. | 141 | 0 | 49.4 ↓ | 45.8 ↓ | 45.8 ↓ |
| PRESSURE * | 286 | 0 | 100 ↓ | 93 ↓ | 93 ↓ |
| AIRLOAD | -406 | 0 | -142 ↑ | -132 ↑ | -132 ↑ |
| MOMENTS | | 0 | -643 ↑ | 359 ↓ | 284 ↓ |
| | | | -635.6 ↑ | 365.8 ↓ | 290.8 ↓ |

SUCTION OFF.-10° CASE - $\bar{z} = 30$ PSF

| LOAD | | ROD | A | B | C |
|--------------|-------|-----|---------|----------|----------|
| | | 0% | 35% | 32.5% | 32.5% |
| WEIGHT COMP. | 197 | 0 | 69 ↓ | 64 ↓ | 64 ↓ |
| PRESSURE * | 320 | 0 | 112 ↓ | 104 ↓ | 104 ↓ |
| AIRLOAD | 63.13 | 0 | 22.1 ↓ | 20.5 ↓ | 20.5 ↓ |
| MOMENTS | | 0 | 664 ↓ | -295 ↑ | -369 ↑ |
| | | 0 | 867.1 ↓ | -106.5 ↑ | -180.5 ↑ |

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| LOAD | | ROD | A | B | C |
|--------------|--------|-----|----------|----------|----------|
| | | 0% | 35% | 32.5% | 32.5% |
| WEIGHT COMP. | 188 | 0 | 65.8 ↓ | 61.1 ↓ | 61.1 ↓ |
| PRESSURE * | 320 | 0 | 112 ↓ | 104 ↓ | 104 ↓ |
| AIRLOAD | -443.8 | 0 | -155.4 ↑ | -144.2 ↑ | -144.2 ↑ |
| MOMENTS | | 0 | -222.5 ↑ | 148.5 ↓ | 74 ↓ |
| | | 0 | -200.1 ↑ | 169.4 ↓ | 94.9 ↓ |

+ 45° CASE - $q = 18$ PSF

| LOAD | | ROD | A | B | C |
|--------------|------|-----|----------|---------|---------|
| | | 0% | 35% | 32.5% | 32.5% |
| WEIGHT COMP. | 141 | 0 | 49.4 ↓ | 45.8 ↓ | 45.8 ↓ |
| PRESSURE * | 320 | 0 | 112 ↓ | 104 ↓ | 104 ↓ |
| AIRLOAD | -406 | 0 | 142 ↑ | 132 ↑ | 132 ↑ |
| MOMENTS | | 0 | 643 ↑ | 355 ↓ | 284 ↓ |
| | | 0 | -623.6 ↑ | 376.8 ↓ | 301.8 ↓ |

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -6-1-3 LOAD DISTRIBUTIONSUMMARY OF LOADS ON GAGES & ROD.

| CASE | q PSF | SUCTION ON - OFF | ROD PRELOAD | ROD lb | A lb | B lb | C lb |
|---------------|----------|---------------------|-----------------|-----------|-----------|-----------|-----------|
| (1) -10 | 30 | ON | 200 | 352.48 ↓ | 731.8 ↓ | -232.1 ↑ | -306.1 ↑ |
| +20 | 30 | ON | 200 | 145.52 ↓ | -855.85 ↑ | 117.56 ↓ | 43.02 ↓ |
| +45 | 18 | ON | 200 | 121.10 ↓ | -678.06 ↑ | 326.48 ↓ | 251.48 ↓ |
| (2) -10 | 30 | OFF | 200 | 367.48 ↓ | 718.41 ↓ | -225.85 ↑ | -299.85 ↑ |
| +20 | 30 | OFF | 200 | 140.52 ↓ | -249.25 ↑ | 223.77 ↓ | 49.22 ↓ |
| +45 | 18 | OFF | 200 | 136.5 ↓ | -671.45 ↑ | 332.68 ↓ | 257.68 ↓ |
| (3) -10 | 30 | ON | DISCONNECT 0 | 0 | 855.1 ↓ | -117.5 ↑ | -191.5 ↑ |
| +20 | 30 | ON | 0 | 0 | -212.1 ↑ | 158.4 ↓ | 83.9 ↓ |
| +45 | 18 | ON | 0 | 0 | -635.6 ↑ | 365.8 ↓ | 290.8 ↓ |
| (4) -10 | 30 | OFF | 0 | 0 | 867.1 ↓ | -106.5 ↑ | -180.5 ↑ |
| +20 | 30 | OFF | 0 | 0 | -200.1 ↑ | 169.4 ↓ | 94.9 ↑ |
| +45 | 18 | OFF | 0 | 0 | -623.6 ↑ | 376.8 ↓ | 301.8 ↓ |
| GAGE RATING : | | | | | 800 | 350 | 350 |

↓ GAGE IN TENSION

↑ GAGE IN COMPRESSION.

- NOTES :
- 1 - The gages are designed for cases (1) & (2)
 - 2 - Cases (1) & (3) are measurement cases.
Cases (2) & (4) are tunnel starting cases.
 - 3 - Loads on gages B & C are interchangeable depending on the direction of the side load.

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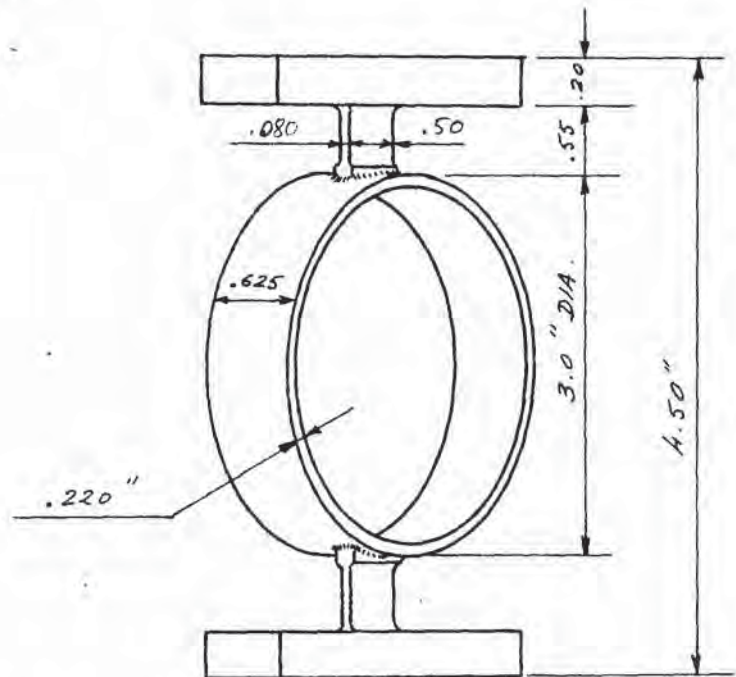
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -6-2 GAGE DESIGN

6-2-1

GAGE A - 800^{lb}

This gage is designed according to report AVRO/SPG/TR-87 for an operating max stress of 40000 PSI at the strain gage section.

Required thickness:

$$t = \sqrt{.07425 K^2 + .545 \times 3 K} - .2725 K$$

$$\text{where } K = \frac{W}{40000b} = \frac{800}{40000 \times .625} = .032$$

$$\therefore t = \sqrt{.07425 \times .032^2 + 1.635 \times .032} - .2725 \times .032$$

$$t = \sqrt{.000076 + .0523} - .008725 = \sqrt{.052376} - .008725$$

$$= .2287 - .0087 = .220"$$

MATERIAL:

AN-QQ-S-689 COND "F"

F_{T_u} : 125000 PSI - F_{T_y} : 100000 PSI - F_{S_u} : 75000 PSI

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -6-2 GAGE DESIGN6-2-1 -GAGE A - Cont'd.

With reference to "Formulas for Stress and Strain" by Roark -

a) Max. bending in the ring at the flexure: $.3183 W R_m$ in/lb

b) Max bending in the ring at the strain gages: $.1817 W R_m$ in/lb

at a), we also have a max shear load = $\frac{W}{2}$ per sectionat b), we also have a tensile or compressive load = $\frac{W}{2}$ per section.

Section modulus of the ring: $\frac{.625 \times .22^2}{6} = .00504 \text{ in}^3$

Sectional area of the ring: $.625 \times .22 = .1375 \text{ in}^2$

Bending moments:

at a/ : $.3183 \times 800 \times \frac{3-.22}{2} = 354 \text{ in/lb}$

at b/ : $.1817 \times 800 \times \frac{3-.22}{2} = 202 \text{ in/lb}$

Stresses at point a/

Bending: $\frac{354}{.00504} = 70200 \text{ PSI}$

Shear : $\frac{800}{2 \times .1375} = 2910 \text{ PSI}$

Principal stress: $\frac{70200}{2} + \sqrt{\left(\frac{70200}{2}\right)^2 + 2910^2} = 70320 \text{ PSI unfactored.}$

Stresses at point b/

Bending : $\frac{202}{.00504} = 40000 \text{ PSI}$

Tension : $\frac{800}{2 \times .1375} = 2910 \text{ PSI}$

Total stress : $40000 + 2910 = 42910 \text{ PSI unfactored.}$

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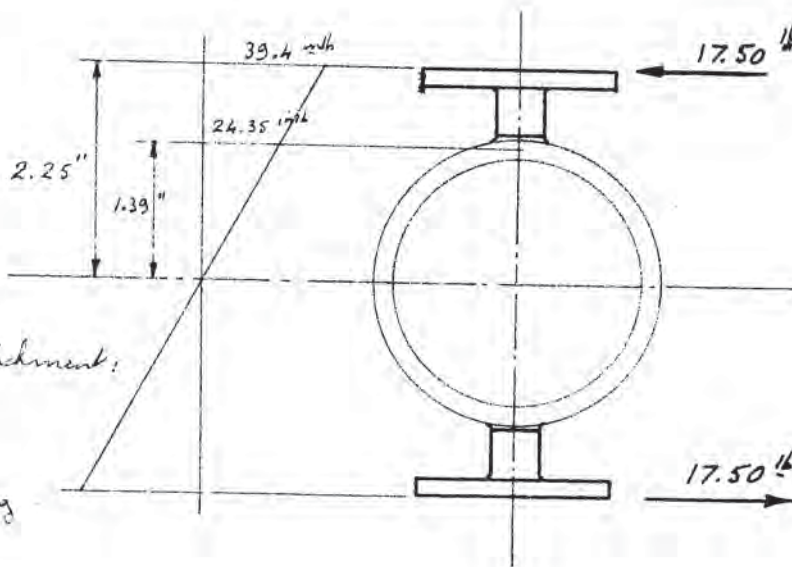
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -

6-2 GAGE DESIGN

6-2-1-

GAGE A - cont'd.



Bending moment at attachment:
 $17.5 \times 2.25 = 39.4 \text{ in lb}$

Bending moment in ring
 attachment:
 $17.5 \times 1.39 = 24.35 \text{ in lb}$

Ring section modulus: $.00504 \text{ in}^3$

Ring sectional area: $.1375 \text{ in}^2$

Bending stress in ring:

$$\frac{12.175}{.00504} = 2420 \text{ PSI}$$

Normal stress: $\frac{8.75}{.1375} = 63.7 \text{ lb}$

Max. total normal stress: $2420 + 63.7 = 2483.7 \text{ PSI}$ say 2500 PSI

Total stress in the ring at this point:

$$2482 + 2500 = 4982 \text{ PSI unfactored.}$$

$$\text{LIM. M.S. } \frac{100000}{49820} - 1 = \text{_____} \quad \text{* - 37}$$

*. This margin of safety is quoted against the actual stress.
 The factor $n=4$ does not apply in this case.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.6-2 GAGE DESIGN6-2-1GAGE A - cont'd.FLEXURES.

From report AVRO/SPG/TR-87 for a flexure operating at 20000 PSI under 800 lb with width $b = .50"$
 thickness $K = .080"$ - Sectional area: $.5 \times .08 = .040 \text{ in}^2$
 Flexure length: $.55"$

The side load on the ring induces a bending moment:
 $17.5 \times 2.05 = 35.9 \text{ in}^2 \text{ lb}$

Section modulus:

$$\frac{.08}{6} \cdot .50^2 = .00333 \text{ in}^3$$

Bending stress:

$$\frac{35.9}{.00333} = 10800 \text{ PSI}$$

Total max normal stress: $20000 + 10800 = 30800 \text{ PSI}$ unfactored.

Stability in compression as per ~~JOHNSON'S~~ FORMULA.

Least moment of inertia: $\frac{.5 \times .08^3}{12} = .00002135 \text{ in}^4$

Radius of gyration $S = \sqrt{\frac{.00002135}{.040}} = \sqrt{.000533} = .0231"$

Slenderness ratio: $\lambda = \frac{.55}{.0231} = 23.8$

Buckling stress: Johnson's formula: $f_c = f_u - \frac{1}{4E} \left(\frac{f_u \lambda}{\pi} \right)^2$

$$f_c = 125000 - \frac{1}{4 \times 3 \cdot 10^7} \left(\frac{125000 \times 23.8}{\pi} \right)^2 = 125000 - \frac{89.5 \cdot 10^{10}}{12 \cdot 10^7}$$

$$= 125000 - 7450 = 117550 \text{ PSI}$$

unfactored: MARGIN OF SAFETY: $\frac{117550}{30800} - 1 = 2.82$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -6-2 GAGE DESIGN6-2-1
GAGE A - CONT'D.ATTACHMENT BOLTS -

Attachment is by means of: 2 - $\frac{1}{4}$ " AN STEEL BOLTS - at each end.
 steel @ 125000 PSI - Tensile strength of one bolt: Ref. AN-C-5: 4080^{lb}

Available strength: $4080 \times 2 = 8160$ ^{lb}

Applied load: max. load with factor of 4:
 $800 \times 4 = 3200$ ^{lb}

$$M.S. \quad \frac{8160}{3200} - 1 = \text{-----} \quad 1.5$$

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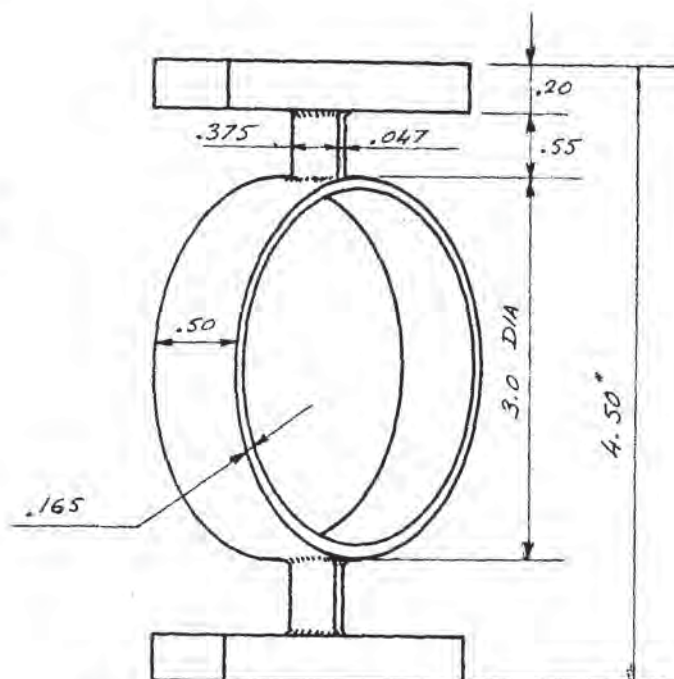
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL6-2 - GAGE DESIGN6-2-2 -
GAGES B & CRATED LOAD : 350 $\frac{1}{2}$ 

This gage is designed according to report AVRO/SPG/TR-87 for an operating max stress of 40000 PSI at the strain gage section:

Required thickness

$$t = \sqrt{.07425 K^2 + .545 \times 3 K} - .2725 K$$

$$\text{where } K = \frac{W}{40000 b} = \frac{350}{40000 \times .50} = .0175$$

$$\therefore t = \sqrt{.07425 \times .0175^2 + .1635 \times .0175} - .2725 \times .0175$$

$$t = \sqrt{.00002275 + .0286} - .004768 = \sqrt{.02862275} - .004768$$

$$= .1693 - .004768 = .16453$$

take .1650"

MATERIAL :

AN - QQ - S - 689 - COND. "F"

F_{tu} : 125000 PSI

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F_{su} : 75000 PSI

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL6-2 GAGE DESIGN6-2-2.GAGE B & C - cont'd.

With reference to "Formulas for stress and strain" by Roark.

a) Max bending in the ring at the flexure: $.3183 W R_m \frac{\text{in} \cdot \text{lb}}{\text{in}^3}$

b) Max. bending in the ring at the strain gages: $.1817 W R_m \frac{\text{in} \cdot \text{lb}}{\text{in}^3}$

at a), we also have a max shear load = $\frac{W}{2}$ per section

at b), we also have a tensile or compressive load = $\frac{W}{2}$ per section.

Section modulus of the ring: $\frac{.50 \times .165^2}{6} = .00227 \text{ in}^3$

Sectional area of the ring: $.50 \times .165 = .0825 \text{ in}^2$

Bending moments:

at a): $.3183 \times 350 \times \frac{3 - .165}{2} = 158 \frac{\text{in} \cdot \text{lb}}{\text{in}^3}$

$.1817 \times 350 \times \frac{3 - .165}{2} = 90.2 \frac{\text{in} \cdot \text{lb}}{\text{in}^3}$

Stresses at point a)

Bending: $\frac{158}{.00227} = 69600 \text{ PSI}$

Shear: $\frac{350}{2 \times .0825} = 2125 \text{ PSI}$

Principal Stress: $\frac{69600}{2} + \sqrt{\left(\frac{69600}{2}\right)^2 + 2125^2} = 70000 \text{ PSI unfactored}$

Stresses at point b)

Bending: $\frac{90.2}{.00227} = 39750 \text{ PSI}$

Tension: $\frac{350}{2 \times .0825} = 2125$

Total Stress: $39750 + 2125 = 41875 \text{ PSI unfactored.}$

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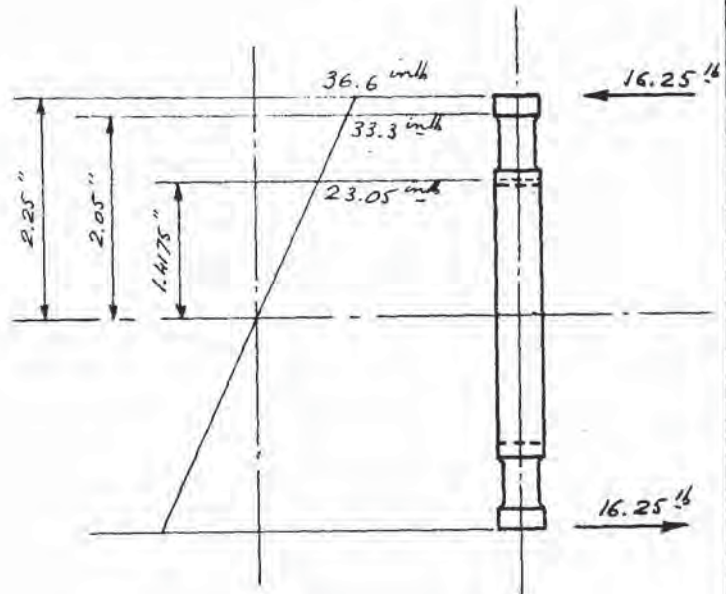
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL6-2 GAGE DESIGN6-2-2GAGES B & C.

Side load on the gages:
 $50 \times .325 = 16.25 \text{ lb}$



Torsional section modulus
of the ring section

$$K = \beta \times .165^2 \times .50$$

$$\beta = .270 \quad \text{for } \frac{.165}{.50} = .330$$

$$K = .27 \times .165^2 \times .50 = .00367 \text{ in}^3$$

Max Torsional shear stress: $\frac{T}{K}$

$$\frac{11.525}{.00367} = 4230 \text{ PSI}$$

Direct shear stress on the section:

$$\frac{8.125}{.0825} = 98.5 \text{ PSI}$$

Total Shear Stress on the section:

$$4230 + 98.5 + 2125 = 6458.5 \text{ PSI}$$

$$\text{Principal stress: } \frac{69600}{2} + \sqrt{\left(\frac{69600}{2}\right)^2 + 6458.5^2} = 70200 \text{ PSI unfactored.}$$

$$\text{LIM M.S. } \frac{100000}{70200} - 1 = \text{---}$$

* This margin of safety is quoted against the actual stress
the factor $n=4$ does not apply in this case.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL6-2 GAGE DESIGN6-2-2GAGES B & CFLEXURES:

From report AVRO/SPG/TR 87, for a flexure operating at 20000 PSI under 350^{lb} with width $b = .375$ " ; thickness $t = .047$ "

Sectional area: $.375 \times .047 = .0176 \text{ in}^2$

Flexure length: $.55$ "

The side load on the ring induces a bending moment:

$$16.25 \times 2.05 = 33.3 \text{ in} \cdot \text{lb}$$

Section modulus:

$$\frac{.047}{6} \times .375^2 = .0011 \text{ in}^3$$

Bending stress:

$$\frac{33.3}{.0011} = 30200 \text{ PSI}$$

Total max stress: $20000 + 30200 = 50200 \text{ PSI}$

Stability in compression as per JOHNSON'S FORMULA.

Least moment of inertia: $\frac{.375 \times .047^3}{12} = 3.25 \times 10^{-6} \text{ in}^4$

Radius of gyration: $S = \sqrt{\frac{3.25 \times 10^{-6}}{1.76 \times 10^{-2}}} = \sqrt{1.85 \times 10^{-4}} = .0136$ "

Slenderness ratio: $\lambda = \frac{.55}{.0136} = 40.4$

Buckling stress: Johnson Formula: $f_c = f_u - \frac{1}{4E} \left(\frac{f_u \lambda}{\pi} \right)^2$

$$f_c = 125000 - \frac{1}{4 \times 3 \times 10^7} \left(\frac{125000 \times 40.4}{\pi} \right)^2 = 125000 - \frac{25.8 \times 10^6}{12 \times 10^7} = 125000 - 21500 = 103500 \text{ PSI}$$

unfactored: MARGIN OF SAFETY: $\frac{103500}{50200} - 1 = \underline{\hspace{2cm}}$ 1.06

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -6-2 - GAGE DESIGN6-2.2GAGES B & C - CONT'D.ATTACHMENT BOLTS -

Attachment by means of : 2 - $\frac{1}{4}$ " AN STEEL BOLTS. at each end.
 Steel @ 125000 PSI - Tensile strength of one bolt : Ref. AN-C-5 : 4080^{lb}

Available strength : $4080 \times 2 = 8160$ ^{lb}

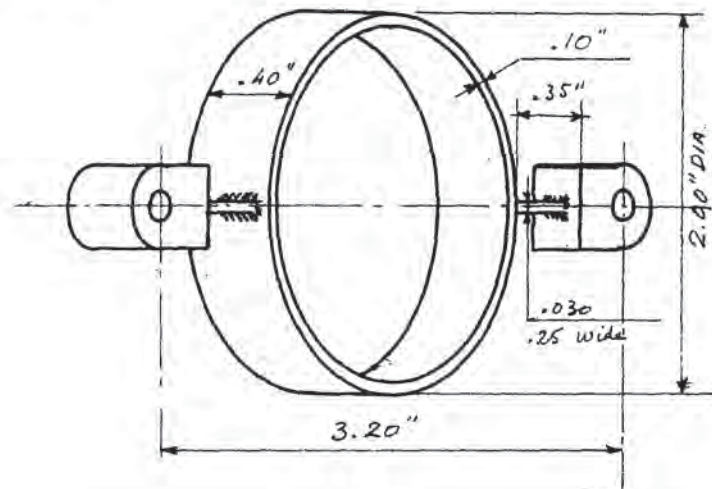
Applied load : max. load with factor of 4
 $350 \times 4 = 1400$ ^{lb}

$$M.S. \frac{8160}{1400} - 1 = \text{-----} 4.8$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.6-2 GAGE DESIGN6-2-3GAGE DRATED LOAD 150^{lb}

This gage is designed according to report AVRO/SPG/TR-87 for an operating max. stress of 40000 PSI at the strain gage section.

Required thickness:

$$t = \sqrt{.07425 K^2 + .545 \times 2K} - .2725 K$$

$$\text{where } K = \frac{W}{40000b} = \frac{150}{40000 \times .40} = .00938$$

$$\therefore t = \sqrt{.07425 \times .00938^2 + .545 \times 2 \times .00938} - .2725 \times .00938$$

$$t = \sqrt{.00000652 + .01025} - .002555 = \sqrt{.01025652} - .002555$$

$$.10127 - .002555 = .09872"$$

$$\text{Say } \underline{\underline{.10"}}$$

MATERIAL:

AN - F9 - S - 689 COND. "F"

$F_{tu} : 125000 \text{ PSI} - F_{ty} : 100000 \text{ PSI} - F_{su} : 75000 \text{ PSI}$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL6-2 - GAGE DESIGN6-2-3GAGE D - cont'd.

With reference to "Formulas for Stress and Strain" by Roark

- a) Max bending in the ring at the flexure: $.3183 W R_m$ in-lb
 b) Max bending in the ring at the strain gages: $.1817 W R_m$ in-lb

at a), we also have a max shear load = $\frac{W}{2}$ per section.

at b), we also have a tensile or compressive load = $\frac{W}{2}$ per section.

Section modulus of the ring: $\frac{.40 \times .10^2}{6} = .000667 \text{ in}^3$

Sectional area of the ring: $.40 \times .10 = .040 \text{ in}^2$

Bending moments:

at a) : $.3183 \times 150 \times \frac{2 - .10}{2} = 46.6 \text{ in-lb}$

at b) : $.1817 \times 150 \times \frac{2 - .10}{2} = 26.6 \text{ in-lb}$

Stresses at point a)

Bending: $\frac{46.6}{.000667} = 70000 \text{ PSI}$

Shear: $\frac{150}{2 \times .040} = 1875 \text{ PSI}$

Principal Stress: $\frac{70000}{2} + \sqrt{\left(\frac{70000}{2}\right)^2 + 1875^2} = 70100 \text{ PSI unfactored.}$

unfactored: LIM. M.S. $\frac{100000}{70100} - 1 = \text{_____}$.43

Stresses at point b)

Bending: $\frac{26.6}{.000667} = 40000 \text{ PSI}$

Tension: $\frac{150}{2 \times .040} = 1875 \text{ PSI}$

Total Stress: $40000 + 1875 = 41875 \text{ PSI unfactored.}$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.6-2 GAGE DESIGN6-2-3GAGE D - cont'd.FLEXURES:

From report AVRO/SPG/TR 87, for a flexure operating at 20000 PSI under 150 lb with width $b = .25"$: thickness $K = .030"$

Flexure length: $.35"$

Sectional area: $.25 \times .03 = .0075 \text{ in}^2$

Stability in compression as per JOHNSON'S FORMULA.

Least moment of inertia: $\frac{.25 \times .03^3}{12} = .5625 \times 10^{-6} \text{ in}^4$

Radius of gyration: $S = \sqrt{\frac{.5625 \times 10^{-6}}{.75 \times 10^{-2}}} = .866 \times 10^{-2} = .00866"$

Slenderness ratio: $\lambda = \frac{.35}{.00866} = 40.5$

Buckling stress: Johnson's formula, $f_c = f_u - \frac{1}{4E} \left(\frac{f_u \lambda}{\pi} \right)^2$

$$\begin{aligned} f_c &= 125000 - \frac{1}{4 \times 3 \times 10^7} \left(\frac{125000 \times 40.5}{\pi} \right)^2 \\ &= 125000 - \frac{1}{12 \times 10^7} \left(25.95 \times 10^4 \right)^2 = 125000 - 21650 \\ &= 103350 \text{ PSI} \end{aligned}$$

MARGIN OF SAFETY: $\frac{103350}{20000} - 1 = \underline{\hspace{2cm}}$ 4.17

NOTE. A large Margin of Safety is necessary on this flexure as bending stresses due to deflection of the other gages could not be assessed with sufficient accuracy.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.6-2 GAGE DESIGN6-2-3GAGE D - CONT'D.Attachment by means of: 1 - $\frac{1}{4}$ " AN STEEL BOLT at each end.

Steel @ 125000 PSI - Bolts in double shear.

Shear strength - Ref AN-C-5 - single shear: 3680 ^{lb}Strength of bolt: $3680 \times 2 = 7360$ ^{lb}

Applied load: max. load with factor of 4:

$$150 \times 4 = 600 \text{ } ^{lb}$$

$$M.S.: \frac{7360}{600} - 1 = \text{—————} > 1$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

6-0 LOAD GAGE DESIGN

6-3 GAGE EQUATIONS - LOAD ON GAGES.

| GAGE | A | B | C | D | |
|----------------|--------------------------|---------------------------|---------------------------|-----------------|--|
| WEIGHT | $.196 W(1-\cos\alpha)$ | $.182 W(1-\cos\alpha)$ | $.182 W(1-\cos\alpha)$ | $W \sin \alpha$ | |
| PRESSURE | $4.47 P_p$ | $4.09 P_p$ | $4.09 P_p$ | 0 | |
| SUCTION | $-2.87 P_s$ | $-2.625 P_s$ | $-2.625 P_s$ | 0 | |
| NORMAL LOAD | $-.196 N$ | $-.182 N$ | $-.182 N$ | 0 | |
| DRAG LOAD | $.760 (D+W \sin \alpha)$ | $-.380 (D+W \sin \alpha)$ | $-.380 (D+W \sin \alpha)$ | D | |
| SIDE LOAD | 0 | $.626 L$ | $-.626 L$ | 0 | |
| PITCHING M_T | $.1575 M_L$ | $-.07875 M_L$ | $-.07875 M_L$ | 0 | |
| ROLLING M_T | 0 | $-.130 M_T$ | $+.130 M_T$ | 0 | |

POSITIVE GAGE LOAD IS TENSION

The load on each gage is the column addition of the load components tabulated above.

WHERE:

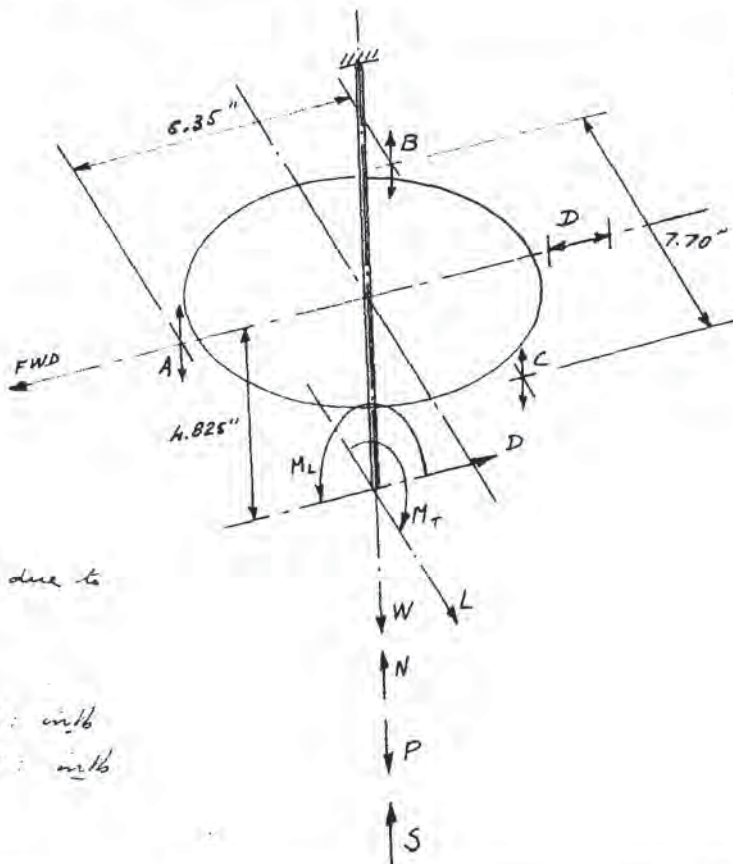
W = model weight: lb

 P_p = pressure in outer pipe: psi g. P_s = pressure in inner pipe: psi g.

N = Normal load on model due to airload: lb

D = Net chordwise force on model due to thrust and airload: lb

L = Side force on model: lb

 M_L = Pitching moment on model: in lb M_T = Rolling moment on model: in lb

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~~SECRET~~STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL7.0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-1 HORIZONTAL TUBE7-1-1 TUBE IN BENDING.SECTION PROPERTIES OF THE TUBE.Size: $7" \times \frac{3}{16}"$ - ID = 6.625"

Sectional area:

$$A = \frac{\pi}{4} (7^2 - 6.625^2) = 3.94 \text{ in}^2$$

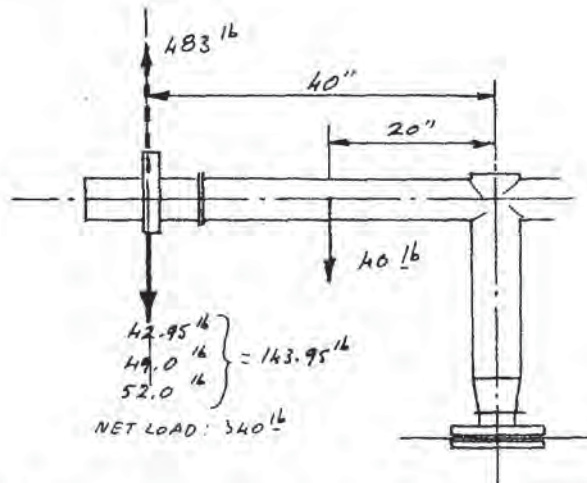
Moment of inertia:

$$I = \frac{\pi}{64} (7^4 - 6.625^4) = 23.3 \text{ in}^4$$

Section modulus:

$$Z = \frac{\pi}{32} \left(\frac{7^4 - 6.625^4}{7} \right) = 6.65 \text{ in}^3$$

The max. support reactions under both static and aerodynamic loading occurs with the incidence of the model at 45° . then:

45° CASE.

REF. SECTION 4-3-3 - & APPENDIX A.

Bending moment under static load.

Bending moment at the center line:

$$M = -(340 \times 40) + (40 \times 20) = -13600 + 800 = -12800 \text{ in} \cdot \text{lb.}$$

Bending moment under model airload

$$\text{Vertically: } 333.1 \times 40 = 13320 \text{ in} \cdot \text{lb}$$

REF. 4-3-5.

$$\text{Horizontally: } 126.1 \times 40 = 5050 \text{ in} \cdot \text{lb}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE.7-1 HORIZONTAL TUBE7-1-1 TUBE IN BENDING45° CASE - CONT'D.

Since airloads relieve the static loads, the critical loads occur with the tunnel off

Then: max. bend. stresses in the tube:

$$f_b = \frac{M}{Z} \quad \text{h} \quad \frac{12800}{6.65} = 7660 \text{ PSI}$$

$$\text{M.S.} \quad \frac{55000}{7660} - 1 = \text{-----} \quad 6.16$$

-10° CASE.

This case is to be considered as bending moments from static load add to bending moment from airload. $(330 - 144) = 186 = R_a$.

Static load:

$$M = (186 \times 40) - (.40 \times 20) = 7440 - 800 = 6640 \text{ inlb.}$$

Airload:

$$\text{Vertical: } 109.31 \times 40 = 4370 \text{ inlb}$$

$$\text{Horizontal: } 13.59 \times 40 = 544 \text{ inlb}$$

Total Bending moment:

$$M_T = \sqrt{(6640 + 4370)^2 + 544^2} = 11024 \text{ inlb}$$

Max bending stress:

$$f_b = \text{h} \quad \frac{11024}{6.65} = 6640 \text{ PSI.}$$

$$\text{M.S.} = \frac{55000}{6640} - 1 = \text{-----} \quad 7.30$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-1 HORIZONTAL TUBE7-1-2 -FLANGES ON 7.00" TUBE.

Bending Moment:

$$340 \times 5 = 1700 \text{ lb} \text{ unfactored.}$$

Shear force:

$$484 - 144 = 340 \text{ lb} \text{ unfactored.}$$

Bolt strength in tension:

Ref. AN-C-5.

$$\text{AN-6} : \frac{3}{8} \text{ " DIA.} : 10100 \text{ lb}$$

$$\text{AN-5} : \frac{5}{16} \text{ " DIA.} : 6500 \text{ lb}$$

Bolt strength in shear:

$$\text{AN-6} : \frac{3}{8} \text{ " DIA.} : 8280 \text{ lb}$$

$$\text{AN-5} : \frac{5}{16} \text{ " DIA.} : 5750 \text{ lb}$$

Centroid of bolt cluster in tension:

$$(10100 - 6500) \frac{4.15}{10100 + (7 \times 6500)} = .269 \text{ "}$$

Distribution of tensions due to bending in the bolt cluster.

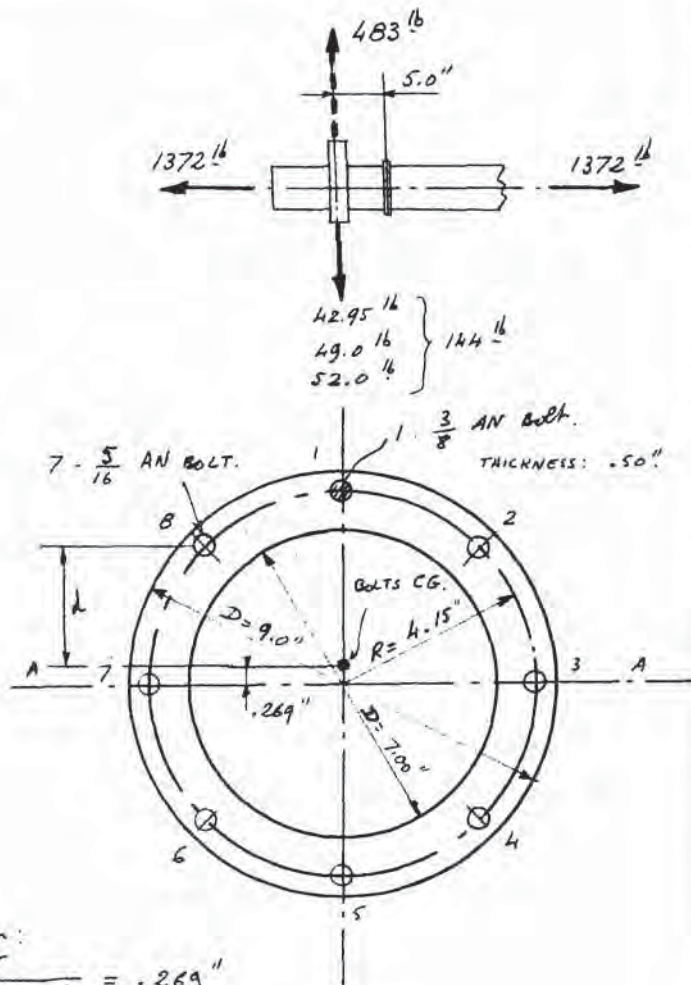
The flange pressure in the compression side is assumed concentrated at the bolts.

With S = the strength of any bolt. F = force on the bolts:
 d = distance of bolts to centroid.

$$F_{ij} = M \frac{d_i S_i}{\sum d^2 S}$$

Direct tension:

$$F_{iT} = T \frac{S_i}{\sum S}$$



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-1 HORIZONTAL TUBE7-1-2.FLANGES ON 7.00" TUBE- CONT'D.

| BOLT. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|------------------------|-------|-------|---------|--------|--------|--------|---------|-------|
| S | 10100 | 6500 | 6500 | 6500 | 6500 | 6500 | 6500 | 6500 |
| d | 3.881 | 2.661 | -.269 | -3.199 | -4.419 | -3.199 | -.269 | 2.661 |
| d ² | 15.1 | 7.1 | -.0725 | 10.12 | 19.55 | 10.12 | .0725 | 7.1 |
| Sd | 39.2 | 17.3 | -1.75 | -20.8 | -28.7 | -20.8 | -1.75 | 17.3 |
| Sd ² | 152.5 | 46.2 | -.471 | 65.8 | 127.0 | 65.8 | -.471 | 46.2 |
| Sd/ΣSd ² | .0778 | .0344 | -.00347 | -.0413 | -.0570 | -.0413 | -.00347 | .0344 |
| $\frac{S}{\Sigma S}$ | .182 | .117 | .117 | .117 | .117 | .117 | .117 | .117 |
| F _{JM} lb | 161.0 | 71.0 | -7.2 | -85.5 | -118.0 | -85.5 | -7.2 | 71.0 |
| F _{JT} lb | 250.0 | 160.5 | 160.5 | 160.5 | 160.5 | 160.5 | 160.5 | 160.5 |
| F _{JTOTAL} lb | 411.0 | 231.5 | 153.3 | 85.0 | 42.5 | 85.0 | 153.3 | 231.5 |

unfactored loads.

$$\Sigma Sd^2 = 504.442$$

$$\Sigma S = 55.6$$

$$\text{Total Bending moment: } 1700 + (1372 \times .269) = 1700 + 369 = 2069 \text{ in}^{\text{lb}}$$

Bolts in Shear:

$$\text{Total shear strength available: } 8280 + (7 \times 5750) = 8280 + 40250 = 48530 \text{ lb}$$

$$\text{Shear on AN-6 Bolt: } 339 \frac{8280}{48530} = 57 \text{ lb} \quad \text{unfactored}$$

$$\text{Shear on AN-5 Bolt: } 339 \frac{5750}{48530} = 40.1 \text{ lb} \quad \text{unfactored}$$

Allowable tension on bolts:

Ref. AN-C-5.

$$Y = b \sqrt{1 - \left(\frac{x}{a}\right)^3} = 10100 \sqrt{1 - \left(\frac{57}{8280}\right)^3} = 10100 \times \sqrt{1 - (.00688)^3}$$

effect of shear is negligible.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-1 HORIZONTAL TUBE7-1-2FLANGES ON 7.00" TUBE - CONT'D.

Margin of Safety on bolts:

$$AN-6 : M.S. : \frac{10100}{4 \times 411} - 1 = \text{_____} 5.14$$

$$AN-5 : M.S. : \frac{6500}{4 \times 231.5} - 1 = \text{_____} 6.03$$

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Margin of Safety on bolts:

$$AN-6 : M.S. : \frac{10100}{4 \times 411} - 1 = \text{_____} \quad 5.14$$

$$AN-5 : M.S. : \frac{6500}{4 \times 231.5} - 1 = \text{_____} \quad 6.03$$

WELD.Assume the load of AN-6 bolt taken by 2" of $\frac{1}{4}$ " weld.

$$\text{Weld area: } 2 \times .25 = .50 \text{ in}^2$$

Allowable UTS of weld metal: 51000 PSI (Ref. AN-C-5)

" USS " " " : 32000 PSI (" ")

$$\text{Weld Stress: } \frac{411}{.5} = 822 \text{ PSI unfactored.}$$

$$M.S. : \frac{32000}{4 \times 822} - 1 = \text{_____} \quad 8.71$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-1-3 MAIN SUPPORT BEARINGS.LUG - CONT'D.Tension:

$$\text{Ratio: } \frac{\text{Width}}{\text{I.D.}} = \frac{7.25 \times 2}{13.38} = 1.083.$$

$$\text{Cof: } K_t = .99 \text{ from graph \#12}$$

$$\text{Tensile stress in the ring: } f_t = \frac{P}{K_t A} = \frac{356 \times 4}{.99 \times 2.5 \times .56} = 1260 \text{ PSI}$$

Bearing:

$$\text{Ratio: } \frac{\text{edge distance}}{\text{I.D.}} \text{ In this case: concentric lug:}$$

$$\therefore \text{Ratio } \frac{\text{edge distance}}{\text{I.D.}} = \frac{\text{Width}}{2 \text{ I.D.}} = \frac{1.083}{2} = .5415$$

$$\text{Cof } K_{br} = .10 \text{ from graph \#13.}$$

$$\text{Bearing stress on the ring: } f_{br} = \frac{P}{K_{br} A} = \frac{356 \times 4}{.10 \times 2.5 \times .56} = 10200 \text{ PSI}$$

Characteristics of material:

AN-S-11. Ref. AVRO DESIGN MANUAL - Sect. II - 3.2, 4.4

UTS: 55000 PSI

UBS: 90000 PSI

YTS: 36000 PSI

MARGINS OF SAFETY:

$$\text{TENSION: } \frac{55000}{1260} - 1 = \underline{\hspace{2cm}} > 10$$

$$\text{BEARING } \frac{90000}{10200} - 1 = \underline{\hspace{2cm}} > 7.8$$

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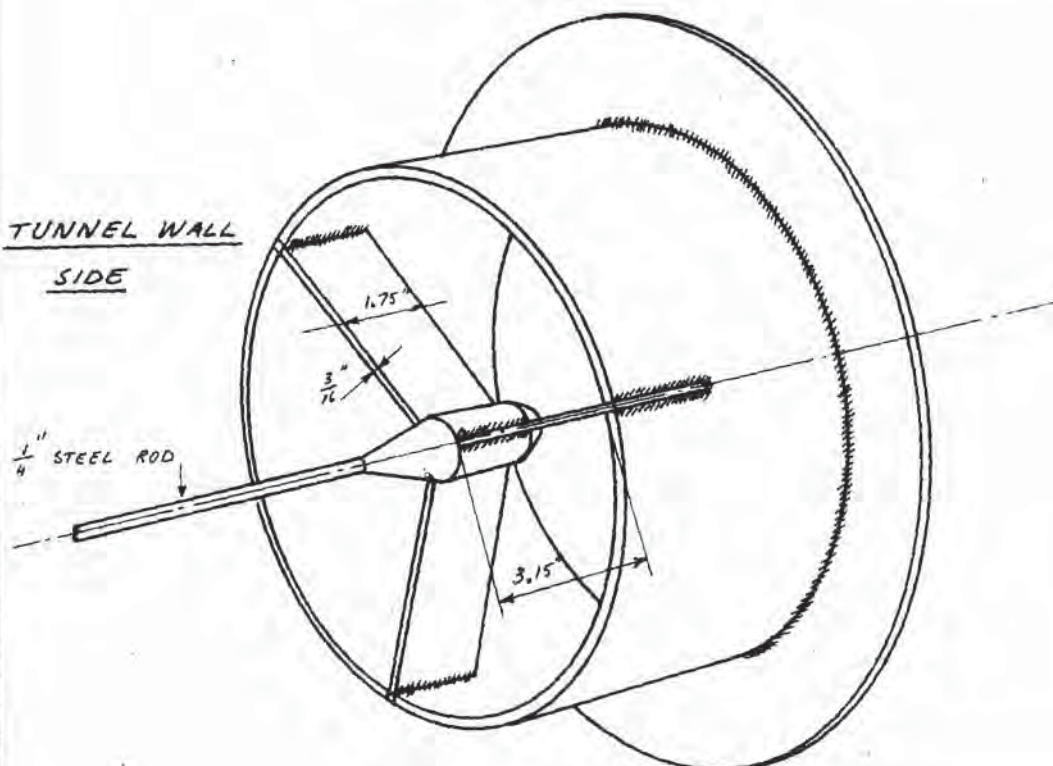
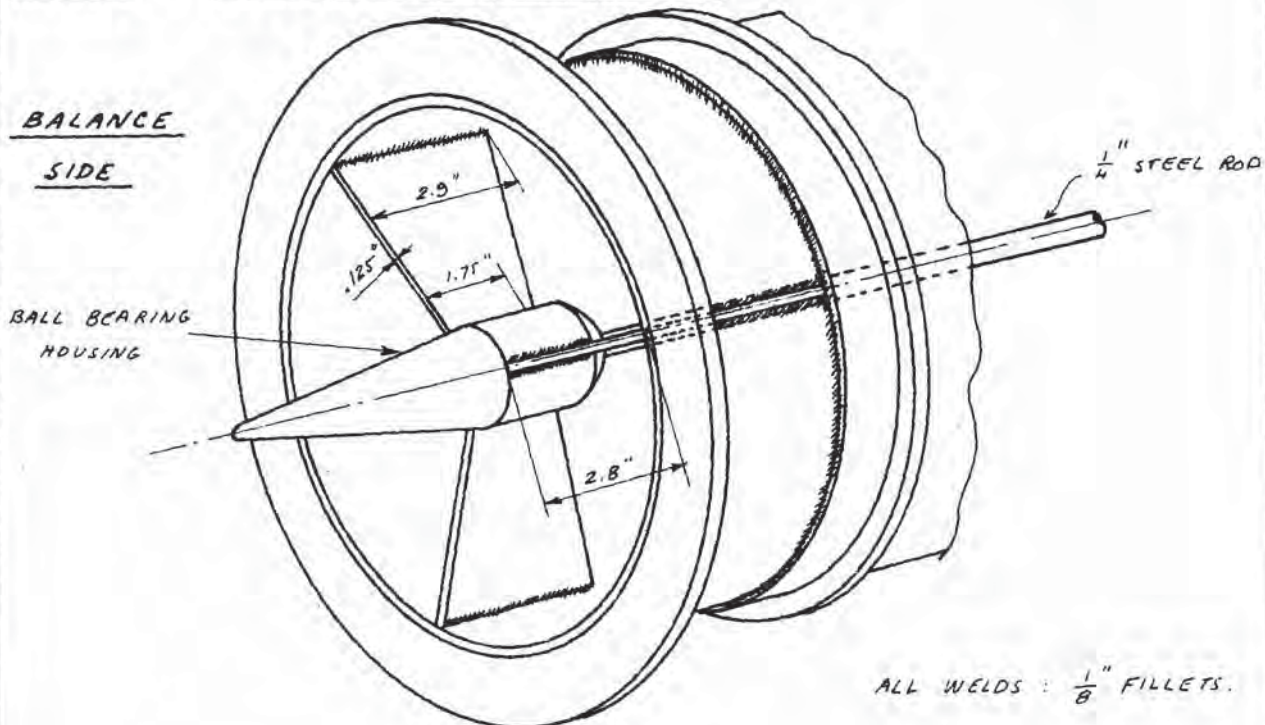
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-1-4 - PRESSURE HOLDING LINK.

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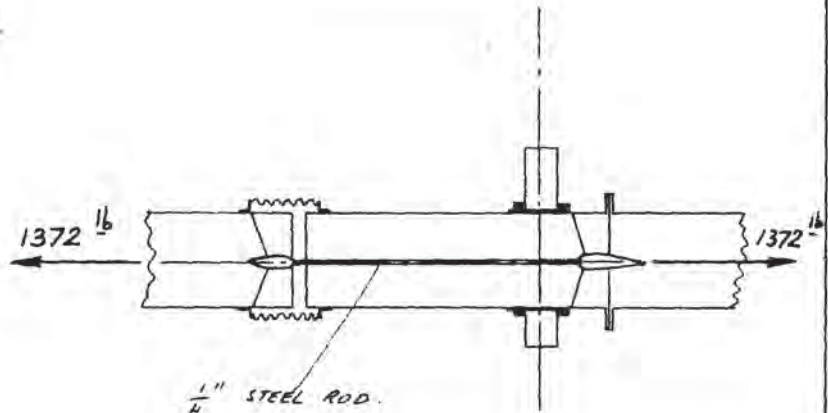
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1-4

PRESSURE HOLDING LINK -



LENGTH IN TENSION: 24.40"

MIN. DIA. AT END OF THREAD: .233"

UNFACTORED LOAD : 1372¹⁶ TENSION.

REF. 4-3-5

FULLY FACTORED LOAD: $1372 \times 4 = 5490^{16}$

Sectional area: $.233^2 \frac{\pi}{4} = .0427 \text{ in}^2$

Genrate stress: $\frac{5490}{.0427} = 128800 \text{ PSI}$

1 - The rod is made of SAE 4130 steel @ 125,000 PSI

MS.

$$\begin{array}{r} 125000 \\ \hline 128000 \end{array}$$

—

ACTUAL M.S.

-.03

3.97

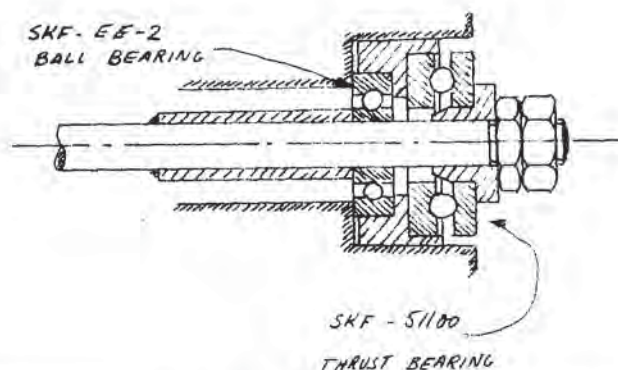
Rod elongation under load: $\frac{1372 \times 24.4}{.0427 \times 30 \times 10^6} = .0262"$

BALL BEARINGS CAPACITY

Ref. SHF. CATALOG. N° 551

EE-2 - Static: 216¹⁶ radial
Dynamic: 430¹⁶ radial.

51100 - Static: 2500^{lb} axial.
Dynamic: 1730^{lb} axial.



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-1-4PRESSURE HOLDING LINK. CONT'D.SKF - BALL BEARINGS:

According to SKF catalogue N° 551 - page 21: "Static Carrying Capacity". The failing load of ball bearings is usually higher than $8 \times$ static load indicated in the tables.

Hence: for the thrust bearing N° 51100: the failing load is approx: $2500 \times 8 = 20000 \text{ lb}$

$$H.S. \quad \frac{20000}{1372} - 1 = \text{---} \quad 13.5$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL7-0 - STRESS ANALYSIS - MODEL SUPPORT STRUCTURE.7-1-H PRESSURE HOLDING LINK.END BRACKETS -BALANCE SIDE.

Each vane takes $\frac{1}{3}$ of the load.

Each vane is fully fixed on the bearing housing and can also be considered as fully fixed on the tail side since it is welded to two rings.

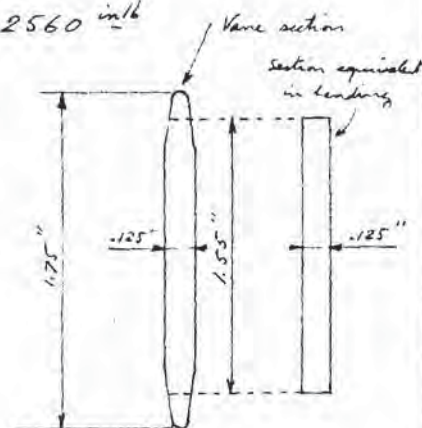
Hence: load in the vane: $1372 \times \frac{4}{3} = 1830 \text{ lb}$ fully factored.

Max bending moment: $1830 \frac{2.8}{2} = 2560 \text{ in lb}$

Section modulus of vane at small end:

$$\frac{1.55^2 \times .125}{6} = .050 \text{ in}^3$$

Bending Stress: $\frac{2560}{.050} = 51200 \text{ PSI}$



$$M.S. \quad \frac{55000}{51200} - 1 = \dots$$

.07

WELD FILLETS:

2 fillets, $.125" \times 1.75"$ taking 2560 in lb bending
+ 1830 lb direct shear.

Ref. AN-C-5. Shear strength of welded joint: 32000 PSI.

Weld area: $2 \times .125 \times 1.75 = .437 \text{ in}^2$

direct Shear stress: $\frac{1830}{.437} = 4180 \text{ PSI}$

Section modulus of weld in shear: $2 \frac{1.75^2 \times .125}{6} = .1272 \text{ in}^3$

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Shear stress due to bending in the weld:

$$\text{max. } \frac{2560}{.1272} = 20150 \text{ PSI}$$

$$\text{Max shear stress in the weld: } \sqrt{20150^2 + 4180^2} = 20600 \text{ PSI}$$

$$\text{M.S. } \frac{32000}{20600} - 1 = \text{---} .55$$

TUNNEL WALL SIDE -Each vane takes $\frac{1}{3}$ of the load

Each vane is fully fixed on the center piece and has some degree of fixing on the tube. It will be assumed that the tube provide a fixing about equal to half that of the center piece

$$\text{Hence: Load on each vane: } 1372 \times \frac{4}{3} = 1830 \text{ lb full fact.}$$

Max Bending Moment:

$$1830 \times \frac{2}{3} \times 3.15 = 3840 \text{ inlb}$$

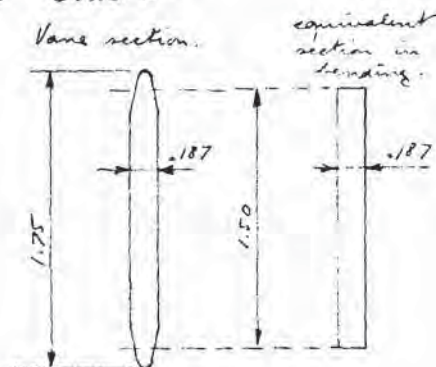
Section modulus of the vane:

$$\frac{1.5^2 \times .187}{6} = .0701 \text{ in}^3$$

Max. bending stress:

$$\frac{3840}{.0701} = 54800 \text{ PSI}$$

$$\text{M.S. } \frac{55000}{54800} - 1 = \text{---} .005$$



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~~SECRET~~STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-1-4 PRESSURE HOLDING LINK.END BRACKETS - CONT'DTUNNEL WALL SIDE - CONT'D.WELD FILLETS.

2 fillets: $.125 \times 1.75"$ taking: $3840 \text{ in}^{\text{lb}}$ bending
+ 1830 lb direct shear.

Ref. AN-C-5: Shear strength of welded joint: 32000 PSI

Weld area: $2 \times .125 \times 1.75 = .437 \text{ in}^2$

Direct shear stress: $\frac{1830}{.437} = 4180 \text{ PSI}$

Section modulus of weld in shear: $2 \frac{1.75^2 \times .125}{6} = .1272 \text{ in}^3$

Shear stress due to bending in the weld:

max: $\frac{3840}{.1272} = 30200 \text{ PSI}$

Max shear stress in the weld: $\sqrt{30200^2 + 4180^2} = 30500 \text{ PSI}$

M.S. $\frac{32000}{30500} - 1 = \text{_____}$.05

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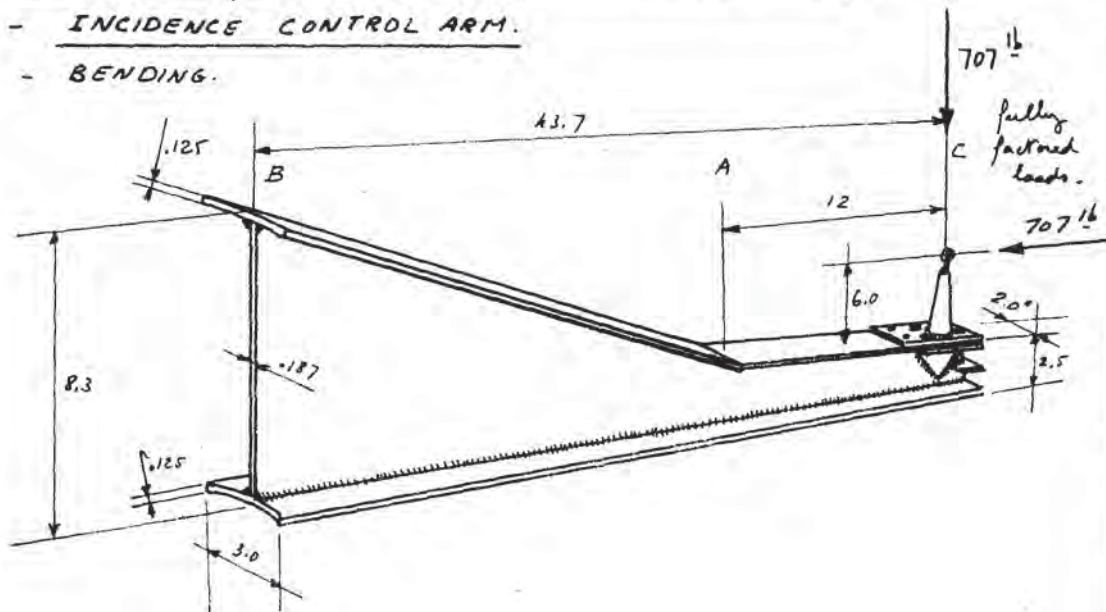
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL-7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-2 - INCIDENCE CONTROL ARM.7-2-1 - BENDING.

Max load on this member is 250 lb when $\alpha = 45^\circ$ and tunnel stopped.

Hence: load normal to the arm and fully factored:

$$\frac{250 \times 4}{\sqrt{2}} = 707 \text{ lb}$$

Compression in the arm: $\frac{250 \times 4}{\sqrt{2}} = 707 \text{ lb}$

Bending Moments:

$$M_C: 707 \times (6 + 2.5 - 1.25) = 707 \times 7.25 = 5120 \text{ inlb}$$

$$M_A: 707 \times (6 + 2.5 - 1.25) - (707 \times 12) = 5120 - 8480 = -3360 \text{ inlb}$$

$$M_B: 707 (6 + 2.5 - 4.15) - (707 \times 43.7) = 3075 - 30900 = -27825 \text{ inlb}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-2-1 INCIDENCE CONTROL ARM. - BENDINGSECTION A & C

$$\text{Sectional area: } 2.5 \times 2 - 2.25 \times 1.813 =$$

$$5 - 4.08 = .92 \text{ in}^2$$

$$\text{Section modulus: } \frac{2.5^2 \times 2 - 2.25^2 \times 1.813}{6} =$$

$$= \frac{13 - 9.22}{6} = .63 \text{ in}^3$$

SECTION B

$$\text{Sectional area: } 8.3 \times 3 - 8.05 \times 2.813 =$$

$$24.9 - 23.4 = 1.5 \text{ in}^2$$

$$\text{Section modulus: } \frac{8.3^2 \times 3 - 8.05^2 \times 2.813}{6} =$$

$$= \frac{207 - 183}{6} = 4 \text{ in}^3$$

Bending stress:

$$\text{Section C: } \frac{5120}{.63} = 8140 \text{ PSI}$$

$$\text{Section B: } \frac{27825}{4} = 6960 \text{ PSI}$$

Compression stress:

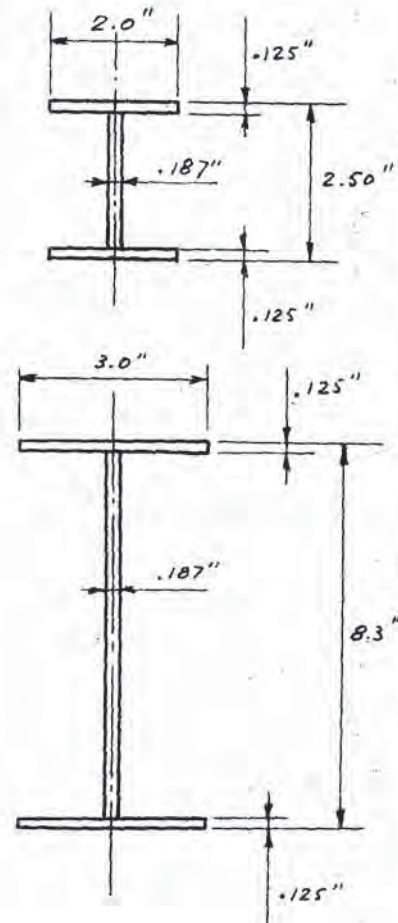
$$\text{Section C: } \frac{707}{.92} = 768 \text{ PSI}$$

$$\text{Section B: } \frac{707}{1.5} = 472 \text{ PSI}$$

Total max stress:

$$\text{Section C: } 8140 + 768 = 8908 \text{ PSI}$$

$$\text{Section B: } 6960 + 472 = 7432 \text{ PSI}$$



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL7-0 - STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-2 - INCIDENCE CONTROL ARM.7-2-1 - BENDINGMARGIN OF SAFETY -

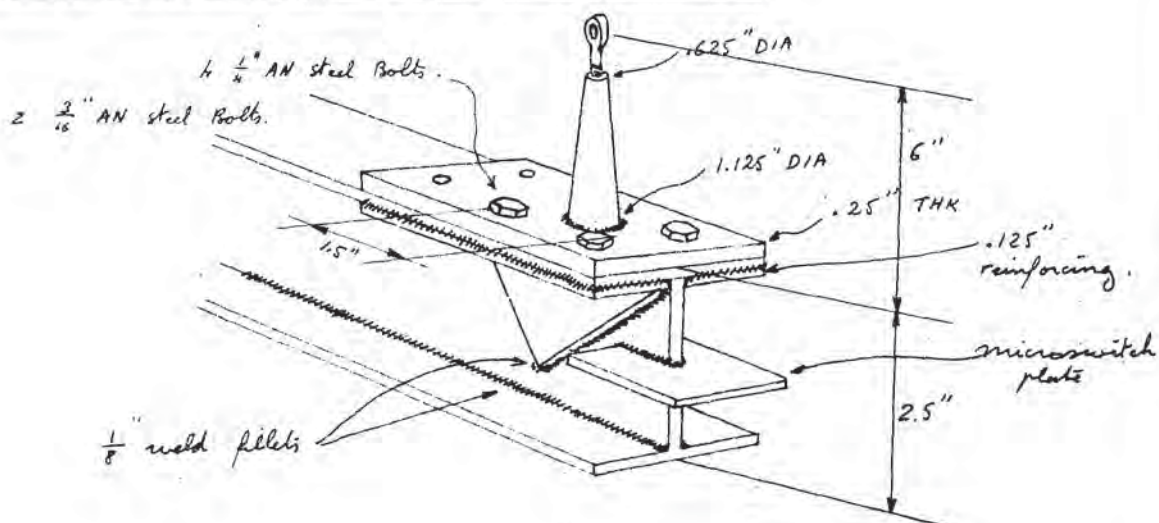
$$\text{Section C: } \frac{55000}{8908} - 1 = \text{_____} \quad 5.18$$

$$\text{Section B: } \frac{55000}{7432} - 1 = \text{_____} \quad 7.40$$

WELD FILLETS - AT SECTION B.

The stresses are the same as those calculated at section B.
The strength of the weld metal is 51000

$$\text{M.S.: } \frac{51000}{7432} - 1 = \text{_____} \quad 5.87$$

7-2-2ATTACHMENT LINK TO BALANCE STRUT.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-2 INCIDENCE CONTROL ARM.7-2-2ATTACHMENT LINK - CONT'D

Circular section in bending + compression at bottom of link.
1.125" dia. SAE 1020 steel.

Bending moment : $707 \times 6 = 4242 \text{ in} \cdot \text{lb}$

Section modulus : $\frac{\pi}{32} D^3 = .0984 \times 1.125^3 = .0984 \times 1.424 = .14 \text{ in}^3$

Sectional area : $\frac{\pi}{4} D^2 = \frac{\pi}{4} \times 1.125^2 = 1.0 \text{ in}^2$

Bending stress : $\frac{4242}{.14} = 30300 \text{ PSI}$

Compression stress : $\frac{707}{1.0} = 707 \text{ PSI}$

Total max. comp. stress : $30300 + 707 = 31007 \text{ PSI}$

M.S. : $\frac{55000}{31007} - 1 = \underline{\hspace{2cm}} .77$

WELD FILLETS -

2 FILLETS. $\frac{1}{8}$ " wide.

Consider the fillets as rings having $\frac{1}{8}$ " width and a mean dia. of 1.125"

$\therefore D = 1.25$ " $d = 1.00$ "

Sectional area : $\frac{\pi}{4} (D^2 - d^2) = \frac{\pi}{4} (1.25^2 - 1^2) = \frac{\pi}{4} \times .56 = .440 \text{ in}^2$

Section modulus : $\frac{\pi}{32} \left(\frac{D^4 - d^4}{D} \right) = .0984 \left(\frac{1.25^4 - 1^4}{1.25} \right) = .0984 \times \frac{2.44}{1.25} = .092 \text{ in}^3$

Hence, for both sections :

$A = .44 \times 2 = .88 \text{ in}^2$

$Z = .092 \times 2 = .184 \text{ in}^3$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-2 INCIDENCE CONTROL ARM.7-2-2ATTACHMENT LINK - CONT'D.WELD FILLETS - CONT'D.

$$\text{Bending stress in the fillet: } \frac{4242}{.184} = 23100 \text{ PSI}$$

$$\text{Compression stress in the fillet: } \frac{707}{.88} = 804 \text{ PSI}$$

$$\text{Total max comp. stress: } 23100 + 804 = 23904 \text{ PSI}$$

$$\text{M.S. } \frac{51000}{23904} - 1 = \text{_____} \quad 1.10$$

7-2-3BASE PLATE.Shear per $\frac{3}{16}$ bolt:

$$\frac{707}{2} = 353.5 \text{ lb}$$

Tension on aft bolts

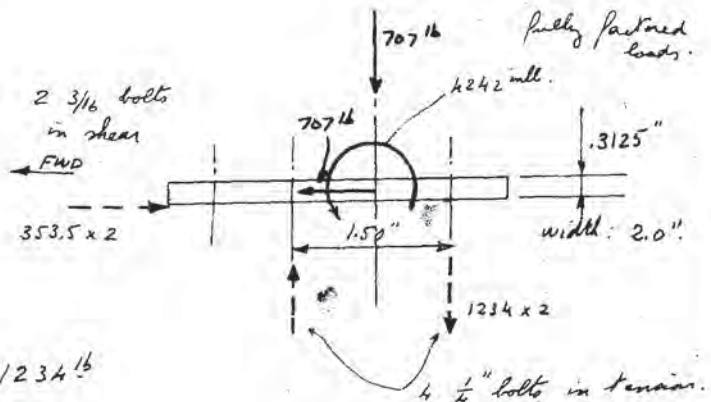
$$\frac{4242}{2 \times 1.5} - \frac{707}{4} = 1410 - 176 = 1234 \text{ lb}$$

Strength of AN-3 steel bolts in shear: 2070 lb (AN-C-5)

$$\text{M.S. } \frac{2070}{353.5} - 1 = \text{_____} \quad 4.85$$

Strength of AN-4 steel bolts in tension: 4080 lb (AN-C-5)

$$\text{M.S. } \frac{4080}{1234} - 1 = \text{_____} \quad 2.3$$



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-2- INCIDENCE CONTROL ARM.7-2-4LOCAL REINFORCEMENTS - CONT'D.SHEAR STRESS IN FILLET N° ①

$$\text{Area of fillet in shear: } .125 \times 2.00 = .25 \text{ in}^2$$

$$\text{Shear on this section: } 1.5 \frac{W}{h} = 1.5 \frac{1234}{.25} = 7410 \text{ lb fully fact.}$$

Shear stress in the weld:

$$\frac{7410}{.25} = 29600 \text{ PSI}$$

$$\text{M.S. } \frac{32000}{29600} - 1 = \text{---} .083$$

NOTE The length of weld has been taken as 1.30" along the length + .70" across the back.

SHEAR STRESS IN FILLET N° ②

It is assumed that $\frac{1}{2}$ of the load is introduced in the $\frac{3}{16}$ " web by the upper $\frac{1}{8}$ " cap. The other half through the reinforcing bracket. The effect of moments will be accounted for by assuming that the whole load is introduced through only one oblique side 3" long.

$$\text{Weld area: } 3.0 \times .125 = .375 \text{ in}^2$$

$$\text{fully factored load: } \frac{1234}{2} = 617 \text{ lb}$$

$$\text{Shear stress in the weld: } \frac{617}{.375} = 16500 \text{ PSI}$$

$$\text{M.S. } \frac{31000}{16500} - 1 = \text{---} .88$$

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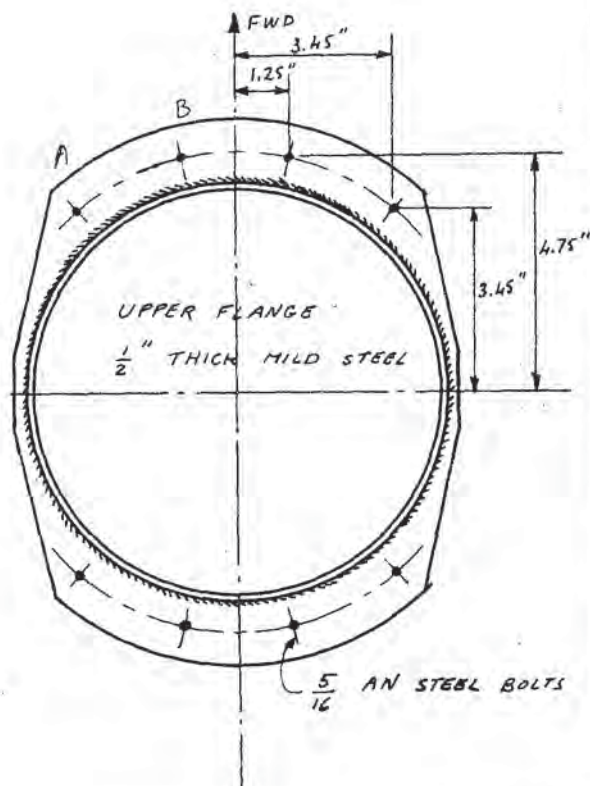
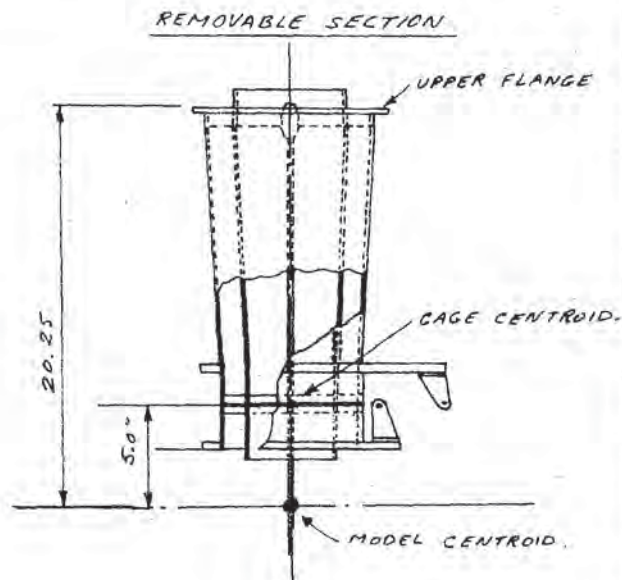
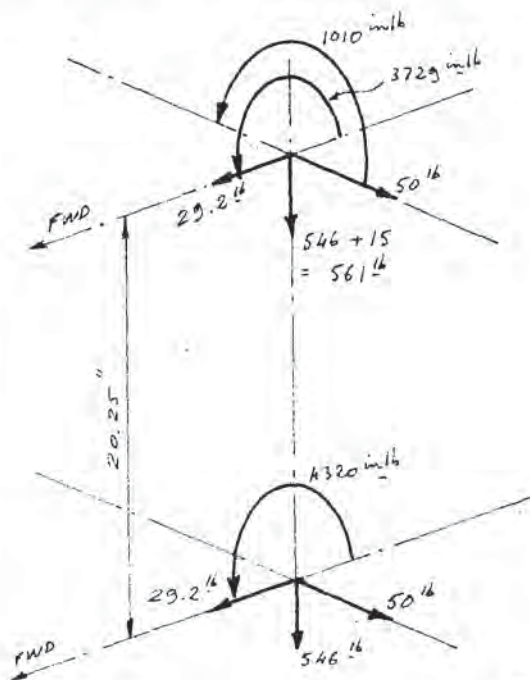
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STRESS ANALYSIS OF $\frac{1}{2}$ SCALE HOVERING & TRANSITION MODEL7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-3-TAPERED SECTION OF VERTICAL ARM.7-3-1 UPPER FLANGE.

Considering the same case as for the gauges (Section 6) and resolving at the upper flange.

-10° Case is the steering case.



Load per bolt due to Vertical load:

$$\frac{561}{8} = 70.2 \text{ lb tension}$$

Total shear on the bolts:

$$\sqrt{29.2^2 + 50^2} = 57 \text{ lb}$$

Shear per bolt: $\frac{57}{8} = 7.25 \text{ lb}$ negligible

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE.7-3-TAPERED SECTION OF VERTICAL ARM- CONT'D.7-3-1 UPPER FLANGE

Loads on the bolts due to moments.

The bolts are stressed as clusters under tension & compression.

Longitudinal moment:

$$\text{Load on bolt B: } \frac{M \times 4.75}{4 \times (4.75^2 + 3.45^2)} = 1.188 \frac{M}{34.5} = .0344 M$$

$$= .0344 \times 4320 = 148.5^{16}$$

$$\text{Load on bolt A: } \frac{M \times 3.45}{4 \times (4.75^2 + 3.45^2)} = .0250 M$$

$$= .025 \times 4320 = 108^{16}$$

Transversal moment:

$$\text{Load on bolt A: } \frac{M \times 3.45}{4 \times (3.45^2 + 1.25^2)} = .862 \frac{M}{13.46} = .064 M$$

$$= .064 \times 1010 = 63.4^{16}$$

$$\text{Load on bolt B: } \frac{M \times 1.25}{4 \times (3.45^2 + 1.25^2)} = .0232 M$$

$$= .0232 \times 1010 = 23.4^{16}$$

$$\text{Total max. load is on bolt: } A = 108 + 63.4 = 171.4^{16} \text{ tension}$$

$$B = 148.5 + 23.4 = 171.9^{16} \text{ tension}$$

Seq $172^{16} + 70.2^{16}$ from direct load on previous page

$$\text{Total unfactored load on one } \frac{5}{16} \text{ AN Bolt: } 172 + 70.2 = 242.2^{16}$$

$$\text{With factor of 4: } 242.2 \times 4 = 968.8^{16}$$

Strength of bolt in tension: Ref. AN-C-5: 6500^{16}

$$M.S.: \frac{6500}{968.8} - 1 = \text{---} \quad 5.7$$

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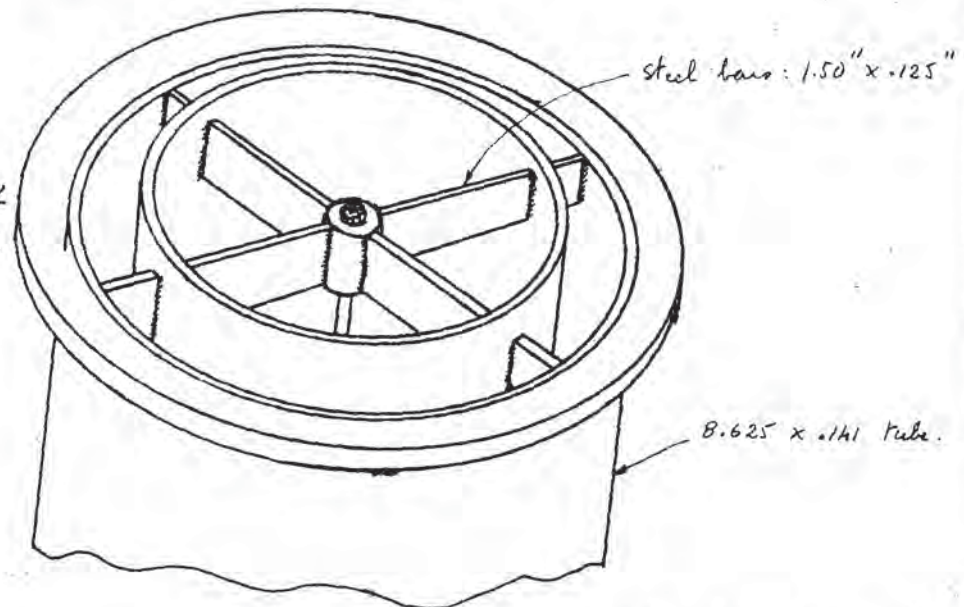
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-3- TAPERED SECTION OF VERTICAL ARM.7-3-2CRUCIFORMBRACKET.MODEL SUSPENSIONROD ATTACHMENT.

This bracket is stressed to have the same strength than the rod in tension.

Strength of the rod: taking strength of equivalent
 $\frac{3}{16}$ AN Bolt @ 125000 PSI - Ref. AN-C-5: 2160 lb say 2200 lb

Each bar of the cruciform bracket takes $\frac{1}{2}$ the load: i.e. 1100 lb.

Max bending moment on the bar:

$$\frac{1100 \times 8.484}{4} = 2210 \text{ in-lb}$$

Section modulus of bar:

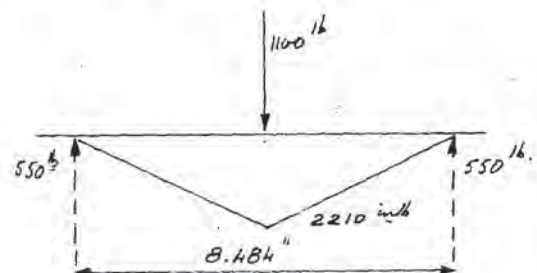
$$\frac{1.5^2 \times .125}{6} = .0468 \text{ in}^3$$

Bending stress:

$$\frac{2210}{.0468} = 47250 \text{ PSI}$$

M.S.

$$\frac{55000}{47250} - 1 = \text{---} +.160$$



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE7-3- TAPERED SECTION OF VERTICAL ARM7-3.2 CRUCIFORM BRACKET.WELD FILLETS ON HUB.

2 $\frac{1}{8}$ " fillets : $.125 \times 1.5$ " taking 2210 in^{lb} bending
+ 550^{lb} direct shear.

Weld section area: $2 \times .125 \times 1.5 = .375$ in²

Direct shear stress: $\frac{550}{.375} = 1470$ PSI

Section modulus of weld in shear:
 $2 \times \frac{1.5^2 \times .125}{6} = .0937$ in³

Shear stress due to bending: $\frac{2210}{.0937} = 26600$ PSI

Total max shear stress: $\sqrt{26600^2 + 1470^2} = 26650$ PSI

M.S. $\frac{32000}{26650} - 1 = \text{_____}$.20

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-3- TAPERED SECTION OF VERTICAL ARM.

7-3-4

MODEL ATTACHMENT.

The load can be assumed to pass entirely into the bolts closest to the gage attachment.

Thus, the attachment can be covered by considering the two bolts taking the load of the 800^{lb} gage.

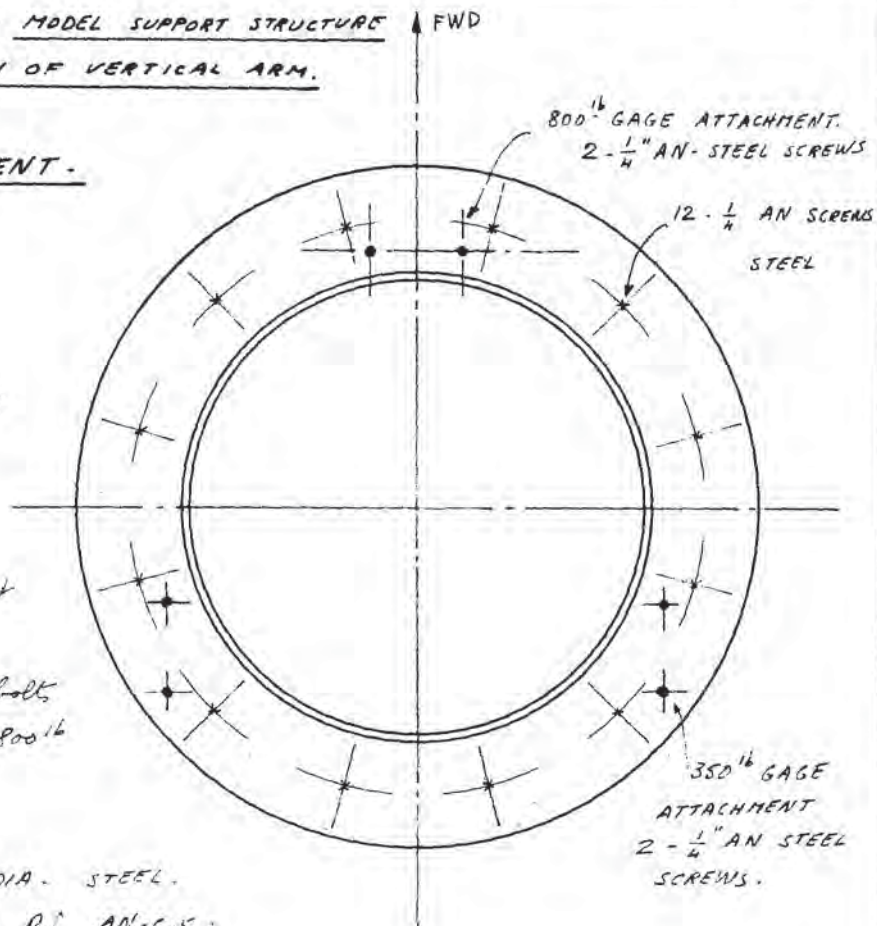
2 AN-SCREWS - $\frac{1}{4}$ " DIA. STEEL.

MAX Tensile strength: Ref AN-C-5:

$$4080 \times 2 = 8160^{lb}$$

$$\text{Factored load: } 800 \times 4 = 3200^{lb}$$

$$M.S. \quad \frac{8160}{3200} - 1 = \text{-----} \quad 1.55$$



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELB-0 STRESS ANALYSIS - FAIRINGB-1HORIZONTAL TUBE.B-1-1 BENDING.Section properties of the tube:

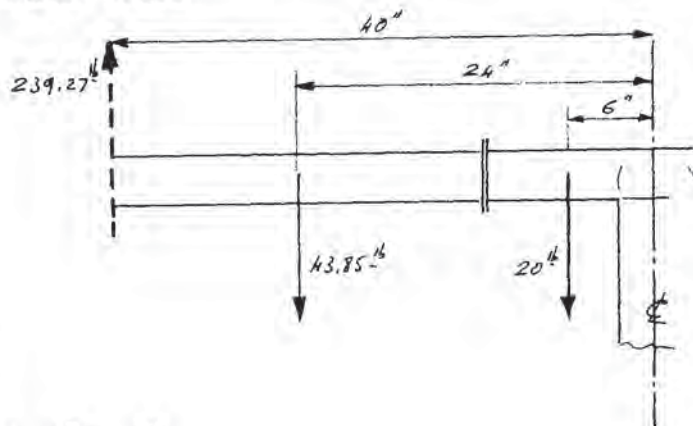
Size: 10" x .141"

ID = 9.718"

Sectional area: $A = \frac{\pi}{4} (10^2 - 9.718^2) = 3.53 \text{ in}^2$

Moment of inertia: $I = \frac{\pi}{64} (10^4 - 9.718^4) = 54 \text{ in}^4$

Section modulus: $Z = \frac{\pi}{32} \frac{10^4 - 9.718^4}{10} = 10.8 \text{ in}^3$

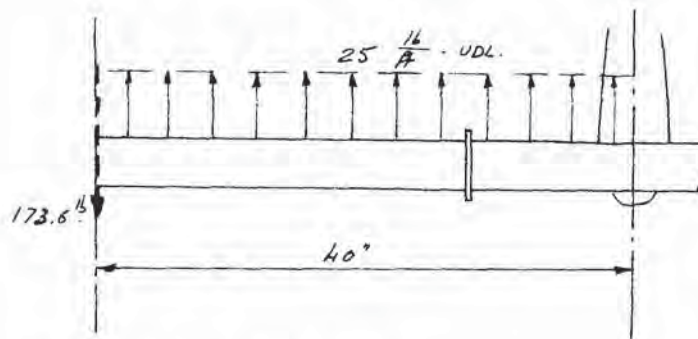
Stresses under static load + airloads:Bending moment under static loads:Bending moment at £.

$$M = (239.27 \times 40) - (43.85 \times 24) - (20 \times 6) = 9560 - 1052 - 120 = 8388 \text{ in-lb}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELB-0 STRESS ANALYSIS - FAIRING.B-1 HORIZONTAL TUBEB-1-1 BENDING.Bending moment
under airload.

Bending moment.

$$M = 173.6 \times 40 - \frac{25 \times 40^2}{2 \times 12} = 6940 - 1666 = 5274 \text{ in}^{\frac{16}{ft}}$$

Total Bending moment on the section:

$$M_T = \sqrt{8388^2 + 5274^2} = 9870 \text{ in}^{\frac{16}{ft}} \text{ (LIN)}$$

Bending stress: max:

$$\frac{4 \times 9870}{10.8} = 3660 \text{ PSI (ULT)}$$

$$M.S. \quad \frac{55000}{3660} - 1 = \text{---} > 10$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELB-0 STRESS ANALYSIS - FAIRINGB-1 HORIZONTAL TUBEB-1-2FLANGES ON 10" TUBE.FLANGE LOADING.

STATIC LOADS : VERTICAL

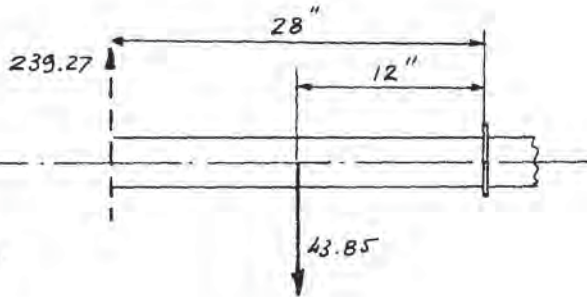
Bending moment at flange section: —

$$(239.27 \times 28) - (43.85 \times 12) =$$

$$6700 - 527 = 6173 \text{ in-lb unfactored.}$$

Shear force:

$$239.27 - 43.85 = 195.42 \text{ lb unfactored.}$$



AIRLOADS : HORIZONTAL

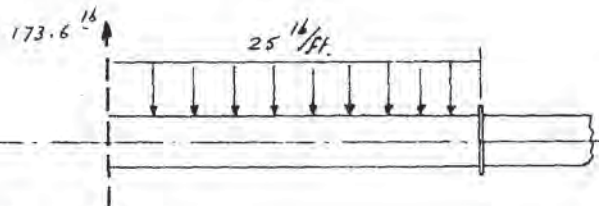
Bending moment at flange section: —

$$(173.6 \times 28) - 25 \frac{28^2}{12 \times 2} =$$

$$4860 - 815 = 4045 \text{ in-lb unfactored}$$

Shear force:

$$173.6 - 25 \frac{28}{12} = 173.6 - 58.3 = 115.3 \text{ lb unfactored.}$$



TOTAL BENDING MOMENT:

$$\sqrt{6173^2 + 4045^2} = 7380 \text{ in-lb unfactored.}$$

Total shear force:

$$\sqrt{195.42^2 + 115.3^2} = 226 \text{ lb unfactored.}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELB-0 STRESS ANALYSIS - FAIRINGB-1 HORIZONTAL TUBEB-1-2.FLANGES ON 10" TUBE -

Bolt strength in tension:

Ref. AN-C-5.

AN-5 - $\frac{5}{16}$ " DIA. : 8500^{lb}

Bolt strength in shear:

AN-5 - $\frac{5}{16}$ " DIA : 5750^{lb}

Distribution of tensions due to bending in the bolt cluster.

$$F_f = \frac{M \frac{d_f}{2}}{\sum d^2}$$

Considering only the bolt having greatest tension.

$$\sum d^2 = 5.6^2 [2 + 4 \sin^2 60^\circ + 4 \sin^2 30^\circ]$$

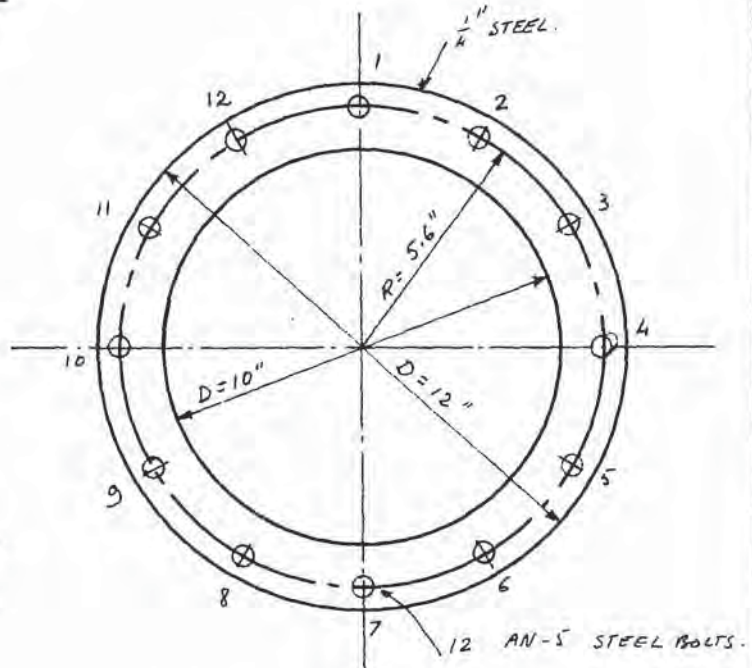
$$\therefore F = \frac{M}{5.6 [2 + 4 \sin^2 60^\circ + 4 \sin^2 30^\circ]} \quad \text{for } d_f = 5.6. \quad F = .0298 M$$

$$\therefore F = 7380 \times .0298 = 220^{\text{lb}} \quad \text{unfactored.}$$

$$\text{Shear per bolt: } \frac{226}{12} = 18.85^{\text{lb}} \quad \text{unfactored.}$$

Such low shear does not practically reduce the tensile strength

$$\therefore \quad \text{M.S.} \quad \frac{8500}{4 \times 220} - 1 = \text{---} \quad 6.4$$



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELB-0 STRESS ANALYSIS - FAIRINGB-1 HORIZONTAL TUBEB-1-2FLANGES ON 10" TUBE.WELDS.Assume max load on bolt to be taken by 2" of $\frac{1}{4}$ " weld.Weld area: $2 \times .25 = .50 \text{ in}^2$

Allowable U.S.S. of weld metal 32000 PSI (Ref. AN-C-5)

Weld stress: $\frac{220}{.50} = 440 \text{ PSI}$ unfactored.

$$M.S. \quad \frac{32000}{4 \times 440} - 1 = \text{_____} \quad 710$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELB-0 STRESS ANALYSIS - FAIRING.B-2 VERTICAL FAIRINGB-2-1 - LOADING.

AREA:

$$(3.11 \times 3.18) - \left(\frac{1.80 \times 1.042}{2} \right) =$$

$$9.88 - .94 = 8.94 \text{ ft}^2$$

Side load on fairing:

$$C_L @ 5^\circ \approx .50$$

Total load at 30 g.

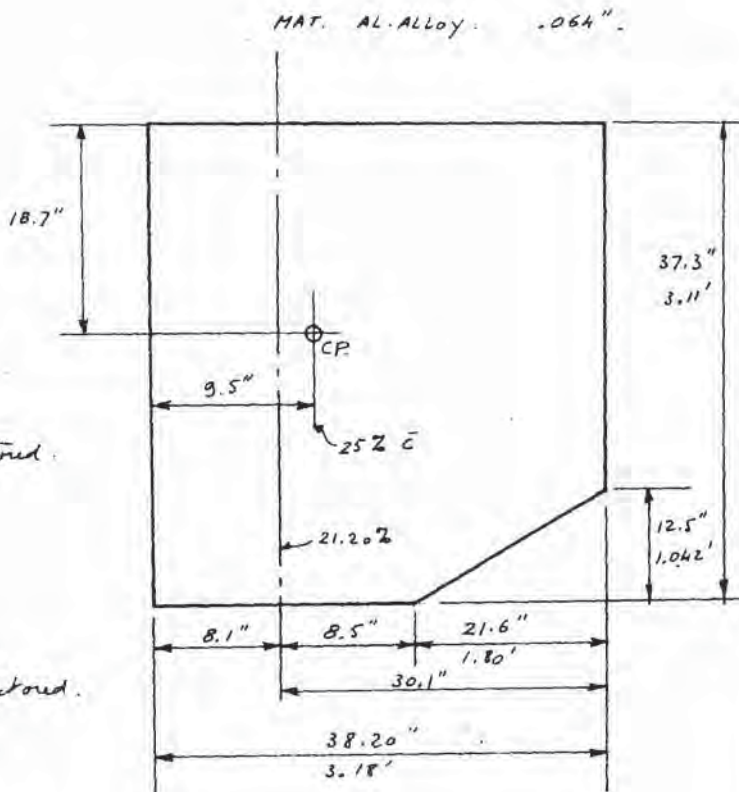
$$.50 \times 8.94 \times 30 = 134 \text{ lb unfactored.}$$

Aft load on fairing:

$$C_D @ 5^\circ \approx .30$$

Total load at 30 g:

$$.30 \times 8.94 \times 30 = 80.5 \text{ lb unfactored.}$$

Fully factored loads: ($n=4$)

$$\text{Side load: } 134 \times 4 = 536 \text{ lb}$$

$$\text{Drag load: } 80.5 \times 4 = 322 \text{ lb}$$

Assuming CP at 25% chord and $\frac{1}{2}$ span:

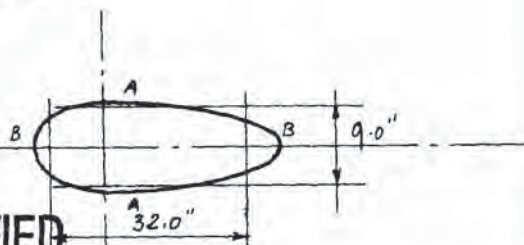
Moments at root

$$\text{SIDE MOMENT: } 18.7 \times 536 = 10000 \text{ in/lb}$$

$$\text{AFT MOMENT: } 18.7 \times 322 = 6020 \text{ in/lb}$$

These moments are considered
as taken by groups of screws
as shown on sketch.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL-B-0 STRESS ANALYSIS - FAIRING.B-2 VERTICAL FAIRING.B-2.2 - VERTICAL FAIRING ATTACHMENT.

Loads on groups of rivets -

$$\text{RIVETS AA: } \frac{10000}{9} = 1120 \text{ lb}$$

$$\text{RIVETS BB: } \frac{6020}{32} = 201 \text{ lb}$$

Bearing strength of $.AD \cdot \frac{5}{32}$ " rivets on $.064$ " 35- $\frac{1}{2}$ H al. alloy.

In the absence of exact data regarding the max. allowable bearing stress on 35- $\frac{1}{2}$ H, this stress is taken as being twice the UTS. by comparison with other similar soft al. all.

$$\text{UTS} = 20000 \text{ PSI (Ref. Engineering Manual)}$$

$$\therefore \text{UBS} = 2 \times 20000 = 40000 \text{ PSI.}$$

Bearing strength on $.064$ (AN-C-5) for $\frac{C}{D} = 2.0$.

$$1020 \frac{40000}{100000} = 408 \text{ lb}$$

The 1120 lb load is to be taken by rivets at 2.00" pitch. and a length of: 12" will be interested to take this load. Hence 6 rivets having a total strength of: $6 \times 408 = 2448 \text{ lb}$

$$\text{M.S. } \frac{2448}{1120} - 1 = \underline{\hspace{2cm}}$$

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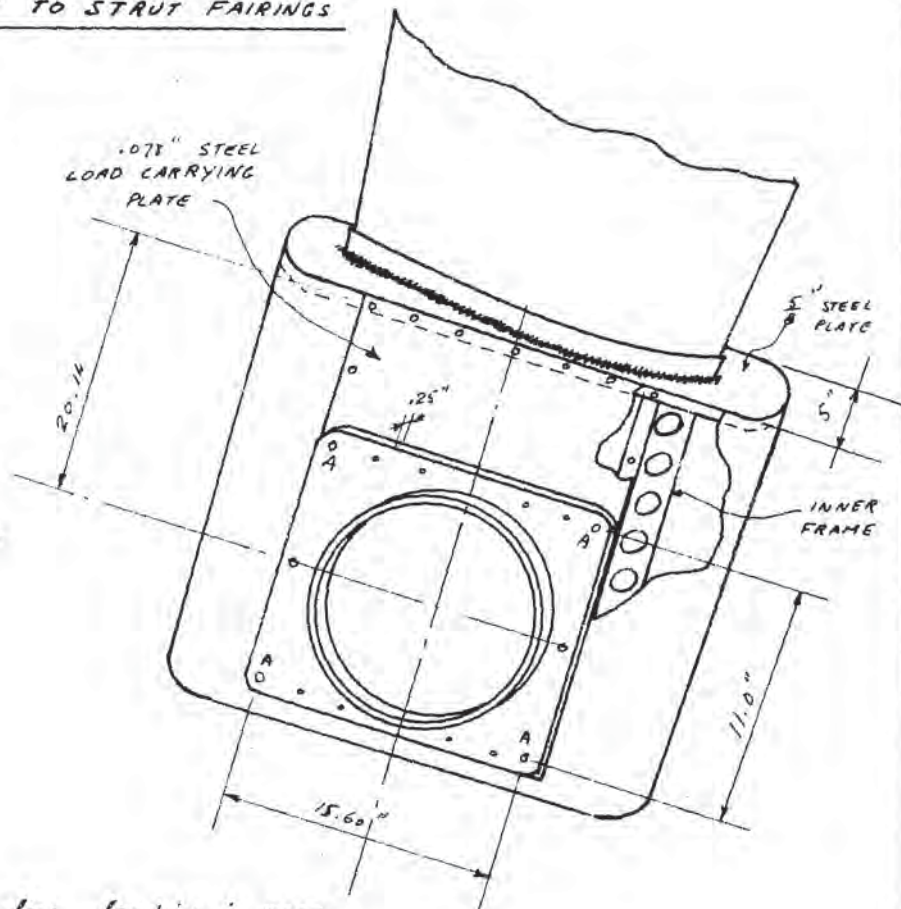
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELB-0 STRESS ANALYSIS - FAIRINGB-3 ATTACHMENT TO STRUT FAIRINGSB-3-1 LOADING.

NOTE: Bolt "A" join
flanges on both sides
and are blocked tight
on a tube spacer

Flanges offset to load
carrying plate:

inner flange: .95"

outer flange: 1.50"

APPLIED LOADS:

On the inner side where loading is max.

240^{lb} Vertically down.

174^{lb} Horizontally aft.

80.5^{lb} Side load due to Vertical fairing

} unfactored.

NOTE: The side load is taken on the Port side only.

FULLY FACTORED APPLIED LOADS

$n = 4.0$

960^{lb} Vertically down

696^{lb} Horizontally aft.

322^{lb} Side load.

NOTE: - Loads on the outer side are smaller than on the inner side.
- As a cover up steering, only load on the inner side will be considered.

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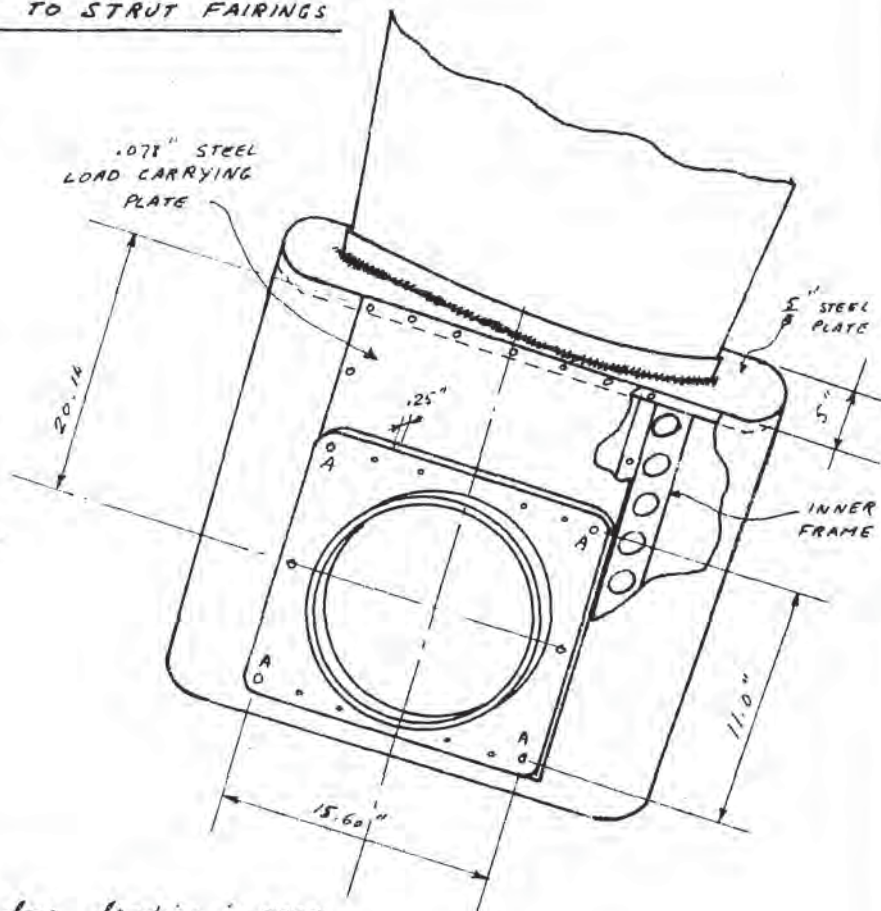
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELB-0 STRESS ANALYSIS - FAIRINGB-3 ATTACHMENT TO STRUT FAIRINGSB-3-1 LOADING.

NOTE: Bolts "A" join flanges on both sides and are blocked tight on a tube spacer.

Flanges offset to load carrying plate:

inner flange: .95"

outer flange: 1.50"

APPLIED LOADS:

On the inner side where loading is max.

240^{lb} Vertically down.

174^{lb} Horizontally aft.

80.5^{lb} Side load due to vertical fairing

} unfactored.

NOTE: The side load is taken on the Port side only.

FULLY FACTORED APPLIED LOADS

$n = 4.0$

960^{lb} Vertically down

696^{lb} Horizontally aft.

322^{lb} Side load.

NOTE: - Loads on the outer side are smaller than on the inner side.
- As a cover up stressing, only load on the inner side will be considered.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELB-0 STRESS ANALYSIS - FAIRINGB-3 ATTACHMENT TO STRUT FAIRINGB-3-2LOAD CARRYING STEEL PLATE-

Max. Vertical load:

$$960 + 322 \frac{20.14}{5} = 960 + 1300 = 2260^{lb}$$

Load per bolt due to 2260^{lb}

$$\frac{2260}{7} = 323^{lb}$$

Load per bolt due to side load:

$$\frac{696}{7} = 99.4^{lb}$$

Load on bolts due to moment of side load:

$$\text{Moment: } 696 \times 20.14 = 14000 \text{ in}^{lb}$$

Load on bolt 1

$$14000 \frac{7.8}{(7.8^2 + 5.2^2 + 2.6^2)2} = 14000 \frac{7.8}{189.6} = 73.9 \times 7.8 = 577^{lb} \text{ Vertical.}$$

$$\text{Load on bolt 2 : } 73.9 \times 5.2 = 384^{lb} \text{ Vertical.}$$

$$\text{Load on bolt 3 : } 73.9 \times 2.6 = 192^{lb} \text{ Vertical.}$$

$$\text{Total load on bolt 1 : } \sqrt{(323 + 577)^2 + 99.4^2} = 905^{lb}$$

Strength of bolt in shear: Ref. AN-C-5: 2126^{lb}

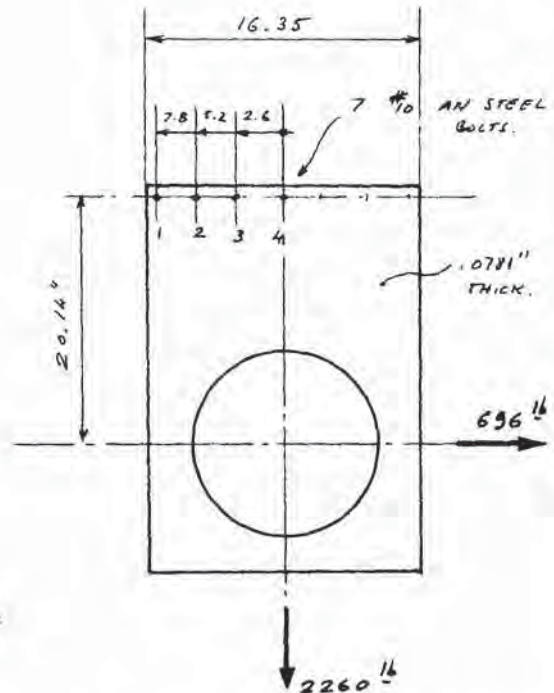
$$M.S. \frac{2126}{905} - 1 = \underline{\hspace{2cm}} \quad 1.34$$

Steel plate: Strength of a 1" strip under tension at UTS: 55000 PSI

$$1" \times .0781 \times 55000 = 4300^{lb}$$

Assuming a 1" strip carries the load to bolt 1.

$$M.S. : \frac{4300}{905} - 1 = \underline{\hspace{2cm}} \quad 3.75$$



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELB-0 STRESS ANALYSIS - FAIRINGB-3 ATTACHMENT TO STRUT FAIRINGSB-3-3.BEARING FLANGES

Load per bolt due to

322^{lb} tension:

$$\frac{322}{6} = 53.7^{lb}$$

Tension on upper bolts

due to moment of

vertical load:

$$960 \frac{1}{11.0} \times \frac{1}{2} = 43.6^{lb}$$

Tension on side bolts

due to moment of

horizontal load:

$$696 \frac{1}{15.6} \times \frac{1}{3} = 14.9^{lb}$$

$$\text{Max tension on one bolt: } 53.7 + 43.6 + 14.9 = 112.2^{lb}$$

Total shear strength of the assembly - (Bearing not critical) Ref. AN-C-5

$$(6 \times 3680) + (14 \times 862) = 22100 + 12050 = 34150^{lb}$$

$$\text{Shear per bolt: } V \frac{3680}{34150} = .108 V$$

$$\text{Total shear force: } \sqrt{960^2 + 696^2} = 1182^{lb}$$

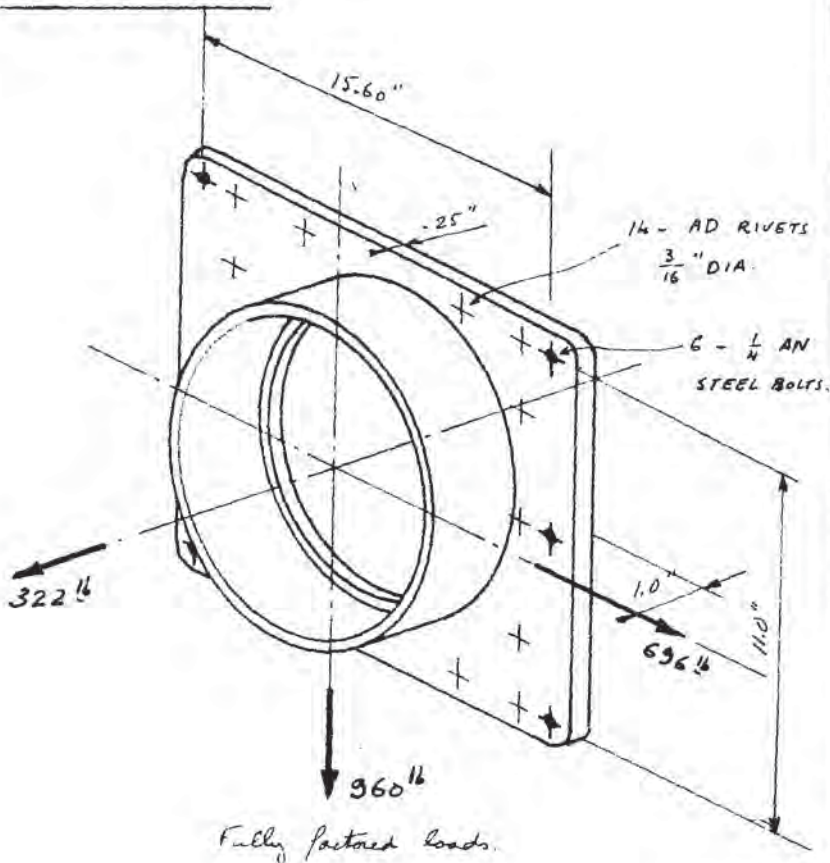
$$\text{Shear per bolt: } 1182 \times .108 = 128^{lb}$$

Strength of $\frac{1}{4}$ AN steel bolt, (AN-C-5) Tension: 4080^{lb}

Shear: 3680

M.S.

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STRESS ANALYSIS OF $\frac{1}{2}$ SCALE HOVERING & TRANSITION MODELB-0 STRESS ANALYSIS - FAIRINGB-3 ATTACHMENT TO STRUT FAIRINGS.B-3-3.BEARING FLANGES - CONT'D.FLANGE IN BENDING UNDER LOAD OF CORNER BOLT.Bolt tension: 112.2^{16} Moment arm 4.00"Section in bending: $.25" \times 8"$ Section modulus: $.25^2 \frac{8}{6} = .0832 \text{ in}^3$ Bending stress: $\frac{112.2 \times 4.0}{.0832} = 5400 \text{ PSI}$ M.S. $\frac{55000}{5400} - 1 =$

9.2

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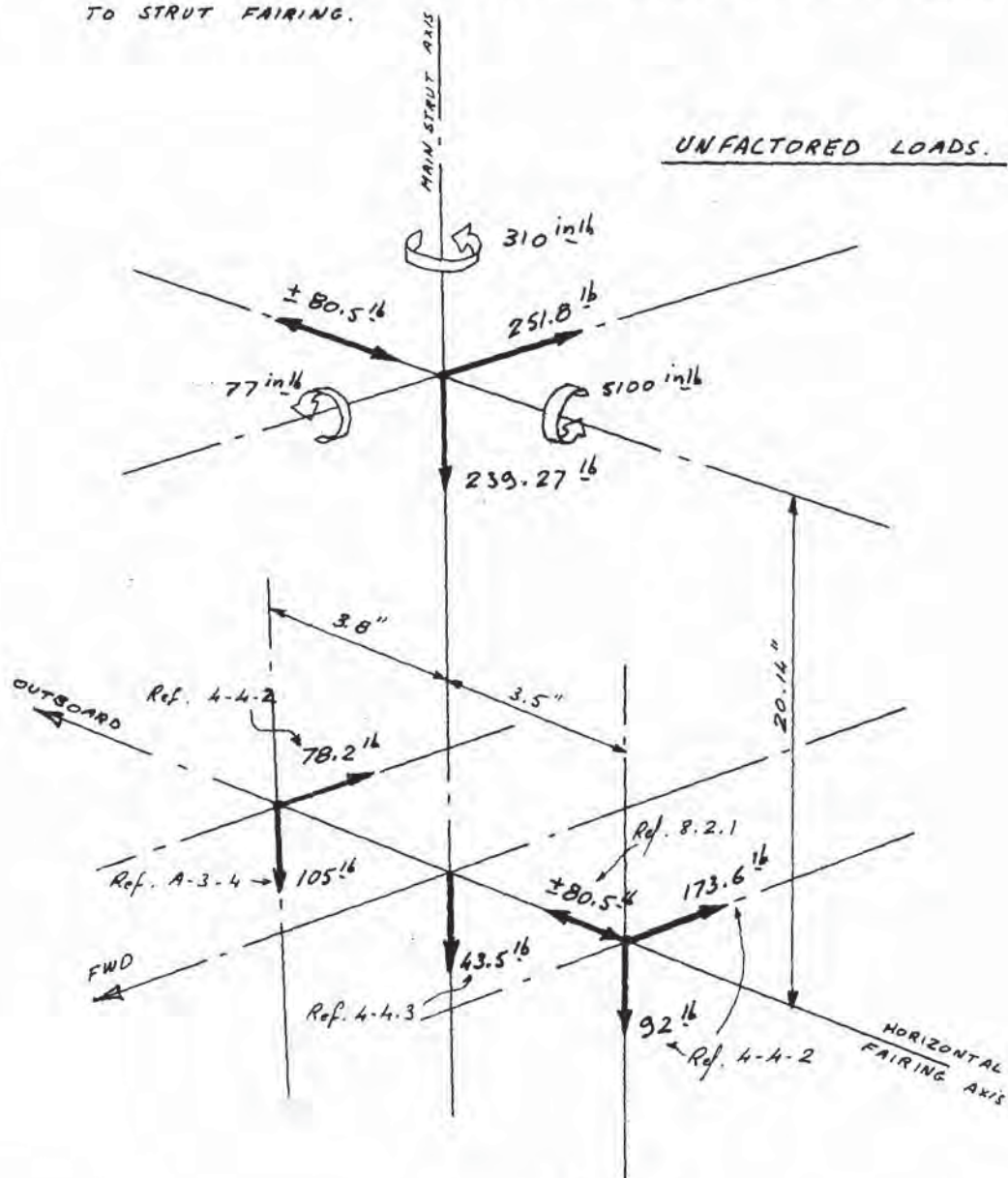
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.B-0 STRESS ANALYSIS - FAIRING.B-3 ATTACHMENT TO STRUT FAIRING.B-3-4 LOADS RESOLVED AT ATTACHMENT TO STRUT FAIRING.

LOADING REQUIRED FOR DESIGN BY WPAFB OF ATTACHMENT
FLANGE ITEM 420 SK 30290 - FAIRING ASS'y ATTACHMENT
TO STRUT FAIRING.



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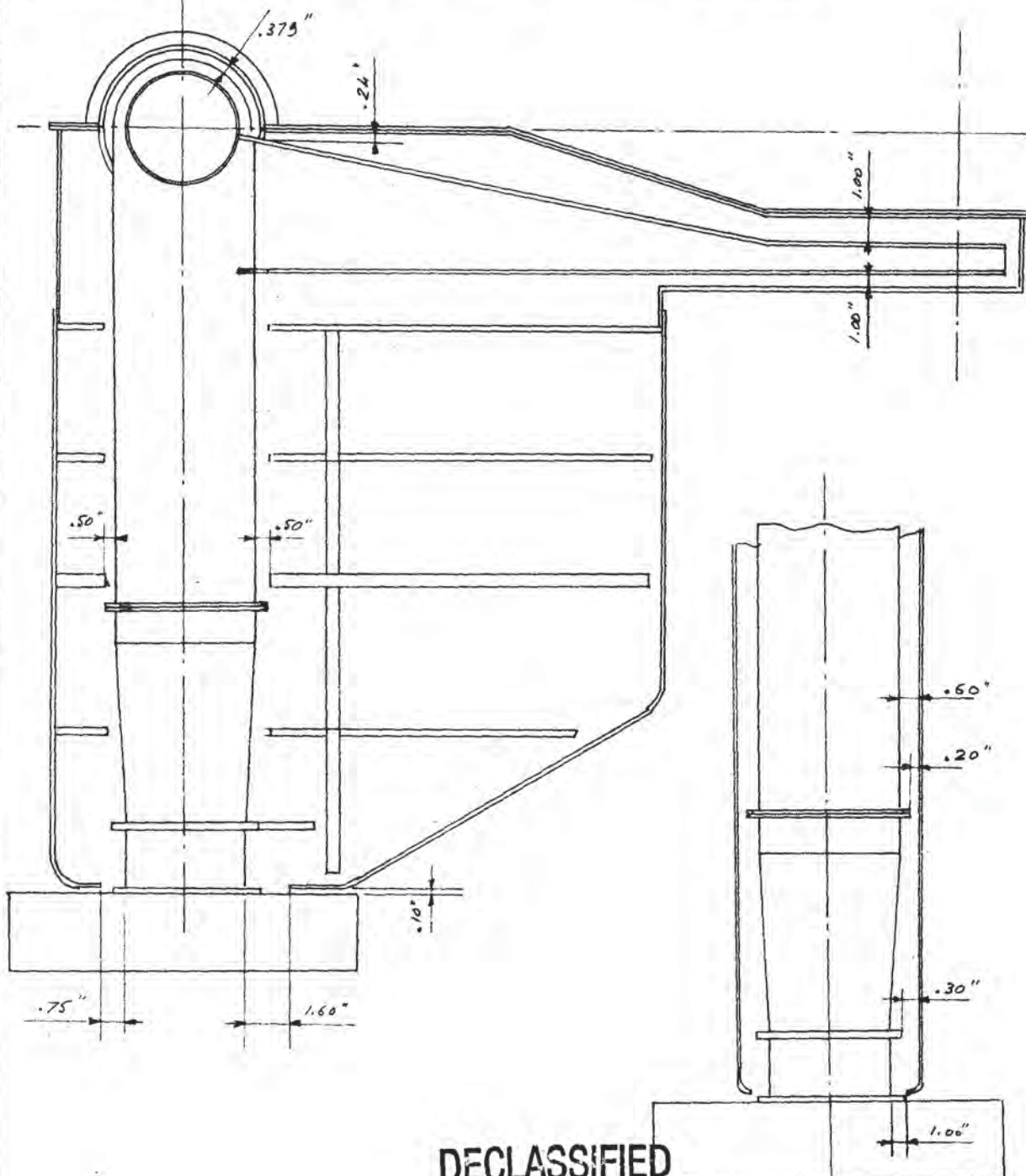
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.9-0DEFLECTIONS.9-1NOMINAL MINIMUM CLEARANCES -FIG-11

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL3-0 DEFLECTIONS3-2 GAGE SECTION DEFLECTION.

The gages are designed as per report: AVRO/SPG/TR-87.

GAGE A - 800^{lb}

OUTER D/A. 3.00"

WIDTH: $b = .625"$

Operating Stress: 40,000 PSI

Thickness: $t = .220$

$$\frac{D}{t} = 13.63$$

GAGE B & C - 350^{lb}

OUTER D/A. 3.00"

WIDTH: $b = .500"$

Operating Stress: 40,000 PSI

Thickness: $t = .165$

$$\frac{D}{t} = 18.20$$

GAGE DEFLECTION AND ROTATION OF MODEL.

$$\text{GAGE A: } \int_{800} = .0213" \quad \therefore \int_1 = \frac{.0213}{800} = 2.66 \times 10^{-5} \frac{\text{in}}{\text{lb}}$$

$$\text{GAGE B \& C: } \int_{350} = .0260" \quad \therefore \int_1 = \frac{.0260}{350} = 7.42 \times 10^{-5} \frac{\text{in}}{\text{lb}}$$

ROTATION OF MODEL UNDER 100^{lb} APPLIED AT CENTER.

$$\text{Load on gage A: } 100 \times .350 = 35^{\text{lb}}$$

$$\text{Load on gage B \& C: } 100 \times .325 = 32.5^{\text{lb}}$$

$$\text{Gage A deflection: } 2.66 \times 35 \times 10^{-5} = .000932"$$

$$\text{Gage B deflection: } 7.42 \times 32.5 \times 10^{-5} = .00241"$$

$$\text{Deflection angle of the model: } \frac{.00241 - .000932}{6.3} = .000235 \text{ rad.}$$

$$\text{Rotation of the model in degrees: } 57.3 \times .000235 = .0134^\circ \text{ per } 100^{\text{lb}}$$

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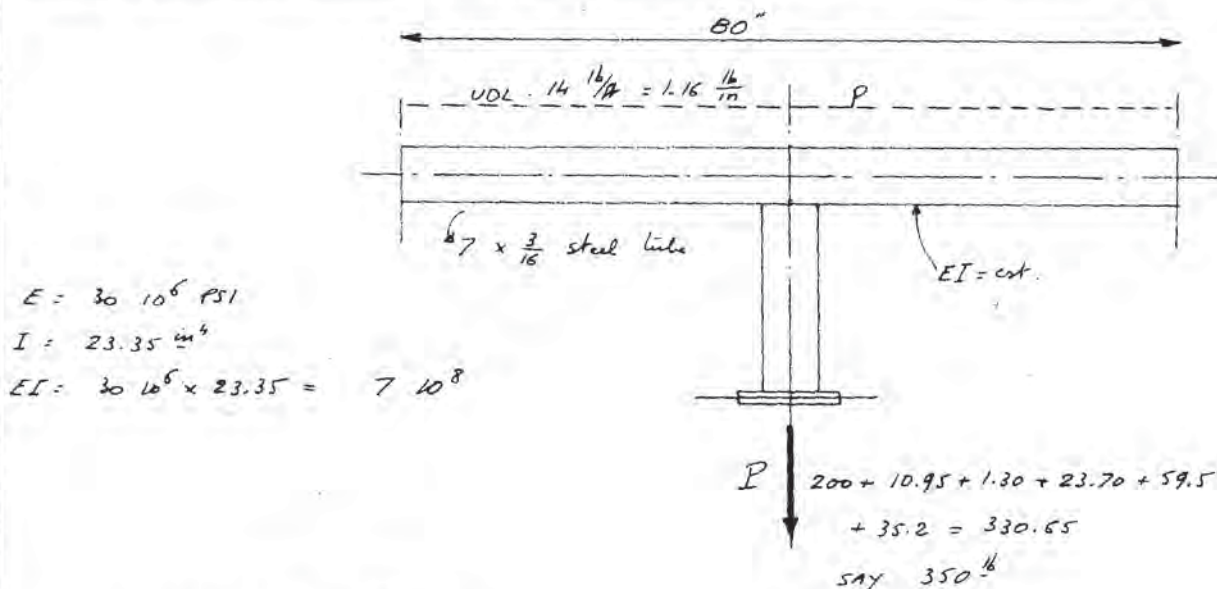
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL9-0 DEFLECTIONS9-3 DEFLECTION OF MODEL SUPPORT STRUCTURE9-3-1DEFLECTION OF MODEL MOUNT UNDER STATIC LOAD. 1 - VERTICAL.

$$E = 30 \times 10^6 \text{ PSI}$$

$$I = 23.35 \text{ in}^4$$

$$EI = 30 \times 10^6 \times 23.35 = 7 \times 10^8$$

DEFLECTION UNDER UDL. P .

$$\delta_1 = \frac{5}{384} P \frac{l^4}{EI} = \frac{.01302 \times 80^4}{7 \times 10^8} P = .00768 P = 7.68 \times 10^{-3} P$$

DEFLECTION UNDER CONCENTRATED LOAD P

$$\delta_2 = \frac{Pl^3}{48EI} = P \frac{80^3}{48 \times 7 \times 10^8} = 1.525 \times 10^{-5} P$$

$$\text{TOTAL DEFLECTION: } \delta = \delta_1 + \delta_2 = 7.68 \times 10^{-2} P + 1.525 \times 10^{-5} P$$

$$\delta = 7.68 \times 10^{-2} \times 1.16 + 1.525 \times 10^{-5} \times 350 = .0089 + .00534 =$$

$$= .01424 \text{ "}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

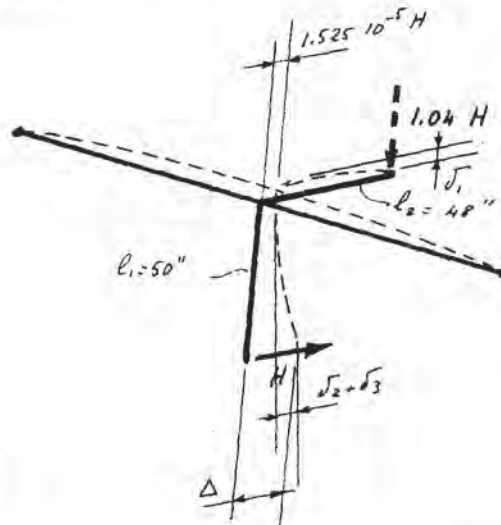
9-0 DEFLECTIONS

9-3 DEFLECTION OF MODEL SUPPORT STRUCTURE

9-3-2

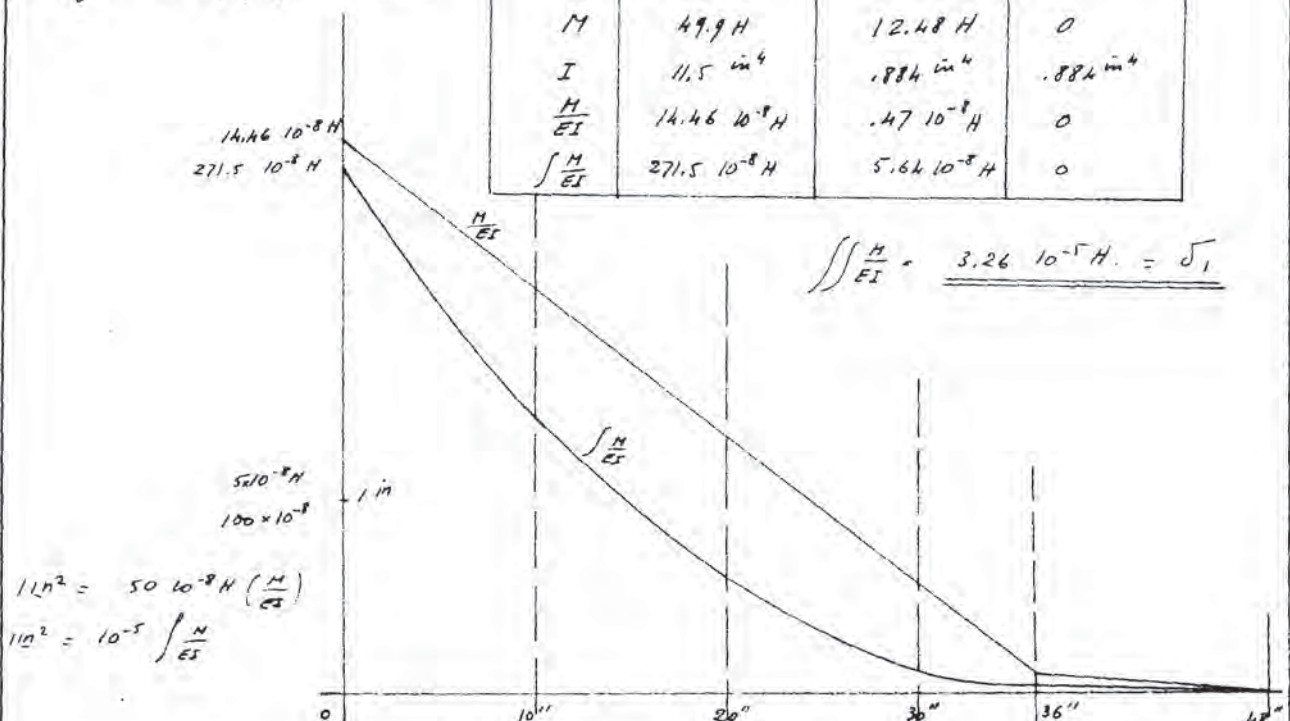
DEFLECTION OF MODEL MOUNT UNDER A DRAG LOAD AT MODEL CENTER.
HORIZONTAL.

The incidence control arm has a variable moment of inertia along its length.



Deflection Calculated
by integrating twice $\frac{17}{EI}$
along the length of the beam

| | C | B | A |
|---------------------|----------------------|----------------------|----------------------|
| ℓ | 48 | 12 | 0 |
| M | 49.9 H | 12.48 H | 0 |
| I | 11.5 in ⁴ | .884 in ⁴ | .884 in ⁴ |
| $\frac{H}{EI}$ | 14.46 10^{-8} H | .47 10^{-8} H | 0 |
| $\int \frac{H}{EI}$ | 271.5 10^{-8} H | 5.64 10^{-8} H | 0 |


$$1 \text{ n}^2 = 50 \cdot 10^{-8} \text{ H} \left(\frac{\text{H}}{\text{m}} \right)$$

$$1 \text{ n}^2 = 10^{-5} \int \frac{N}{ES}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -9-0DEFLECTIONS9-3DEFLECTION OF MODEL SUPPORT STRUCTURE-9-3-2DEFLECTION OF MODEL MOUNT UNDER A DRAG LOAD AT MODEL CENTER - CONT'D.
HORIZONTAL.

$$\delta_1 = 3.26 \cdot 10^{-5} H \quad \text{and} \quad \delta_2 = 3.26 \cdot 10^{-5} \frac{50}{48} H = 3.39 \cdot 10^{-5} H$$

BENDING DEFLECTION OF VERTICAL MEMBER.

$$\delta_3 = \frac{H l^3}{3EI} \quad \text{where } l = 50" \text{ \& } I = 33.75 \text{ in}^4$$

$$\delta_3 = H \frac{50^3}{3 \times 30 \cdot 10^6 \times 33.75} = 4.12 \cdot 10^{-5} H$$

TOTAL HORIZONTAL DEFLECTION OF THE MODEL CENTER:

$$1.525 \cdot 10^{-5} H + 3.39 \cdot 10^{-5} H + 4.12 \cdot 10^{-5} H = 9.035 \cdot 10^{-5} H$$

$$\text{SAY: } \underline{\underline{10^{-4} H = \Delta}}$$

Thus, for a drag load of 200 lb, the deflection is

$$2 \cdot 10^{-4+2} = 2 \cdot 10^{-2} = \underline{\underline{.020"}}$$

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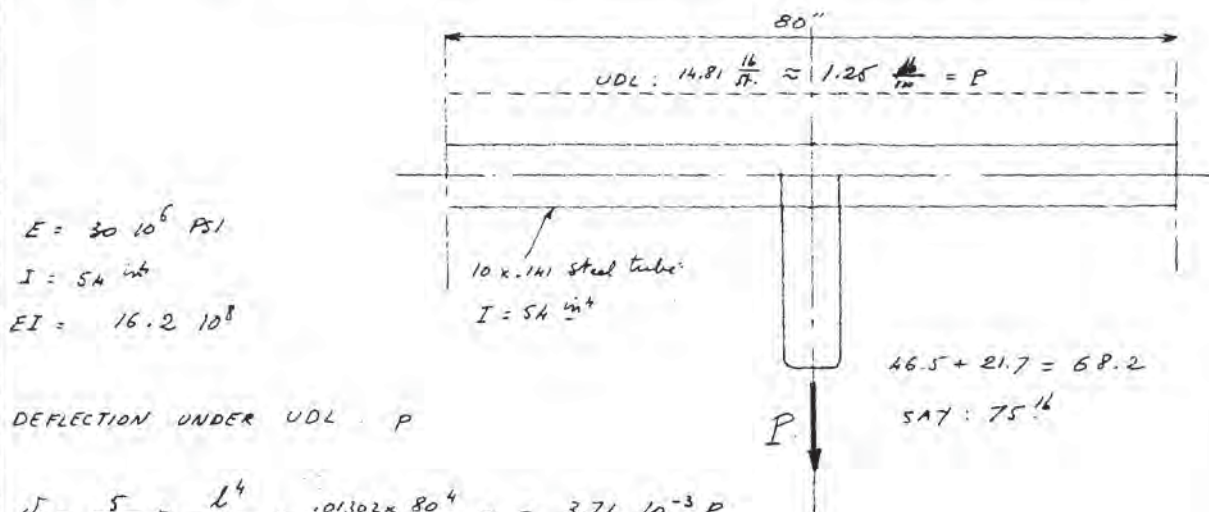
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.9.0 DEFLECTIONS9-4 DEFLECTION OF FAIRING9-4-1DEFLECTION OF FAIRING TUBE UNDER STATIC LOAD. VERTICAL

$$E = 30 \cdot 10^6 \text{ PSI}$$

$$I = 54 \text{ in}^4$$

$$EI = 16.2 \cdot 10^8$$

DEFLECTION UNDER UDL P

$$\delta_1 = \frac{5}{384} P \frac{L^4}{EI} = \frac{.01302 \times 80^4}{16.2 \cdot 10^8} P = 3.71 \cdot 10^{-3} P$$

DEFLECTION UNDER CONCENTRATED LOAD P

$$\delta_2 = \frac{P L^3}{48 EI} = P \frac{80^3}{48 \times 16.2 \cdot 10^8} = .734 \cdot 10^{-5} P$$

$$\text{TOTAL DEFLECTION: } \delta = \delta_1 + \delta_2 = 3.71 \cdot 10^{-3} P + 7.34 \cdot 10^{-6} P$$

$$\delta = 3.71 \cdot 10^{-3} \times 1.25 + 7.34 \cdot 10^{-6} \times 75 = .00468 + .000558$$

$$= .005238''$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL9-0 DEFLECTIONS9-4 DEFLECTION OF FAIRING9-4-2.DEFLECTION OF FAIRING TUBE UNDER AIR LOAD. - HORIZONTAL.

The characteristics are similar to the static load case
with a UCL: $25 \frac{lb}{ft}$: $2.08 \frac{lb}{in}$ say $2.10 \frac{lb}{in}$
and a drag load of $80.5 \frac{lb}{ft}$ from the fairing of the Vertical arm.

Hence Deflection:

$$\delta = 3.71 \cdot 10^{-3} \times 2.10 + 7.34 \cdot 10^{-6} \times 80.5 =$$

$$7.79 \cdot 10^{-3} + 5.92 \cdot 10^{-4} = \underline{\underline{.008382''}}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.9-0 DEFLECTIONS9-5. CONCLUSION -

In view of the clearance provided the deflection under load of this structure is insignificant.

We can see that the smallest clearance is .10" just above the surface of the model. In the static condition, the model mount sinks .0142" while the fairing sinks .0052" hence the relative motion is:

$.0142 - .0052 = .0090"$. Thus approximately 10% of the clearance provided.

Considering the effect of model lift, a critical case is the -10° case with a total down load of 546 lb i.e. an extra 346 lb on the static case which would induce an additional deflection: $1.525 \times 10^{-5} \times 346 = .00527"$

Then, the relative motion becomes:

$.009 + .00527 = .01427"$ about 14% of the clearance provided.

All other clearances are larger hence less critical than the above.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.10-0 CALIBRATION10-0-1 INTRODUCTION

In this section, the symbols and sign convention used in the rest of the report have been replaced by those of report AVRO/SPG/TR 98 "Test Specifications for $\frac{1}{12}$ scale Hovering and Transition Model".

In 10-1-1, the basic gage equations from section 6-3 have been repeated using the new symbols. It should be noted that these equations apply only when the model suspension rod is engaged. When the rod is disengaged, the load distribution on the gages changes to that calculated on 6-1-3 page.

The basic equations from 10-1-1 can be simplified for calibration purpose by noting that:

- 1/ angle $\alpha = 0$
- 2/ Pressure and suction are off

The reduced equations are given in 10-1-2.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL10-0 CALIBRATION10-1 GAGE EQUATIONS FOR CALIBRATION.10-1-1 BASIC GAGE EQUATION.

REF. SECTION 6-1.3 & 6-3

| GAGE | A | B | C | D | |
|----------------|------------------------------|------------------------------|------------------------------|------------------|---------------------------|
| WEIGHT | $.196 W(1-\cos \alpha)$ | $.182 W(1-\cos \alpha)$ | $.182 W(1-\cos \alpha)$ | $-W \sin \alpha$ | |
| PRESSURE | $4.47(P_j - P_a)$ | $4.09(P_j - P_a)$ | $4.09(P_j - P_a)$ | 0 | $A_p = 22.6 \text{ in}^2$ |
| SUCTION | $2.87(P_s - P_a)$ | $2.625(P_s - P_a)$ | $2.625(P_s - P_a)$ | 0 | $A_s = 14.5 \text{ in}^2$ |
| NORMAL LOAD | $-.196 N$ | $-.182 N$ | $-.182 N$ | 0 | |
| DRAG LOAD | $-.760(F - W_{\text{wind}})$ | $+.380(F - W_{\text{wind}})$ | $+.380(F - W_{\text{wind}})$ | F | |
| SIDE LOAD | 0 | $-.626 Y$ | $+.626 Y$ | 0 | |
| PITCHING M_y | $-.1575 M_p$ | $+.07875 M_p$ | $+.07875 M_p$ | 0 | |
| ROLLING M_x | 0 | $.130 M_R$ | $-.130 M_R$ | 0 | |

POSITIVE GAGE LOAD IS TENSION.

NOTE:

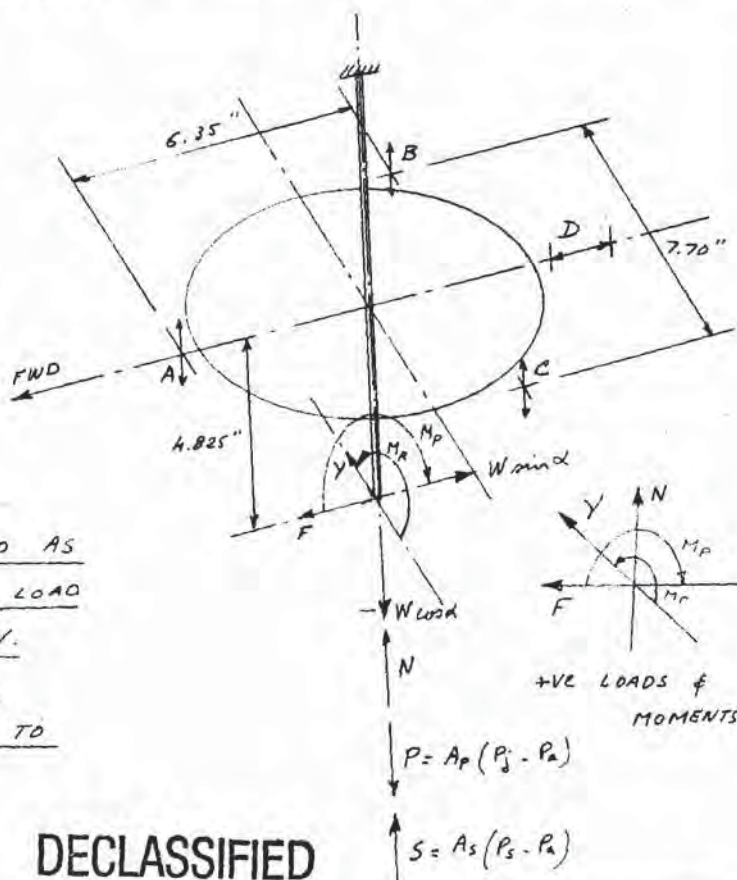
Pressures $(P_j - P_a)$
and $(P_s - P_a)$ in PSI.

TOTAL LOAD ON EACH GAGE

IS THE SUM OF THE
CORRESPONDING COLUMN.

NOTE: ABOVE VALUES ARE VALID AS
LONG AS THE TOTAL NORMAL LOAD
DOES NOT EXCEED $+2.278 W$.

NORMAL LOADS OF THIS
MAGNITUDE ARE NOT EXPECTED TO
OCCUR DURING TESTS.



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL10-0 CALIBRATION10-1 GAGE EQUATIONS FOR CALIBRATION10-1-2 GAGE EQUATIONS & MAX. APPLIED LOADS.VERTICAL LOAD AT WHICH VERTICAL SUSPENSION ROD
WILL DISCONNECT.From Section 6-1-3 : Rod deflection: $J_r = 2.42 \times 10^{-5} W$ Gage system deflection: $J_g = 1.895 \times 10^{-5} W$

From the equation: $\Delta W = W_1 + 1.278 W_1 = 2.278 W_1$,
 where W_1 is the weight of the model and $\Delta W = N$.
 we have:

$$N = 2.278 \times 200 = 456 \text{ }^{lb}$$

MAX. & MIN. LOADS APPLICABLE ON THE SYSTEM TO
REACH RATED GAGE LOADSNORMAL LOAD N.

GAGE A: Equations: $-800 \leq -0.35(N-200) \leq 800$ $\begin{matrix} \text{COMPR.} & & \text{TENS.} \end{matrix}$ $N \geq 456$

$-800 \leq -0.196 N \leq 800$ $\begin{matrix} \text{COMPR.} & & \text{TENS.} \end{matrix}$ $N \leq 456$

Gage load at $N = 456 \text{ }^{lb}$

$$G_1 = -0.35 \times (456 - 200) = -0.35 \times 256 = -89.6 \text{ }^{lb}$$

$$G_2 = -0.196 \times 456 = -89.6 \text{ }^{lb}$$

at Min. Gage load: $G = -0.196 N$

$$N = \frac{800}{-0.196} = -4080 \text{ }^{lb}$$

at Max. Gage load: $G = -0.35(N-200)$

$$N = \frac{-800}{-0.35} + 200 = 2485 \text{ }^{lb}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.10-0 CALIBRATION10-1 GAGE EQUATIONS FOR CALIBRATION10-1-2 GAGE EQUATIONS & MAX. APPLIED LOADS.MAX. & MIN. LOADS APPLICABLE ON THE SYSTEM TO REACH RATED
GAGE LOADS - CONT'D.GAGE B & C

$$\text{Equations: } -350 \leq -.325(N-200) \Big/ N \geq 456 \leq 350$$

$$-350 \leq -.182 N \Big/ N \leq 456 \leq 350$$

Gage load at $N = 456^{lb}$

$$G_1 = -.325(456 - 200) = -.325 \times 256 = -83.2^{lb}$$

$$G_1 = -.182 \times 456 = -83.2^{lb}$$

at min. gage load:

$$G = -.182 N$$

$$\therefore N = \frac{350}{-.182} = \underline{\underline{-1925^{lb}}}$$

at Max. Gage load: $G = -.325(N-200)$

$$\therefore N = \frac{350}{-.325} + 200 = \underline{\underline{1275^{lb}}}$$

PITCHING MOMENT M_p .GAGE A:

$$\text{Equation: } .1575 M_p = G_A = \pm 800^{lb}$$

$$\therefore M_p = \frac{\pm 800}{.1575} = \pm 5080^{in\cdot lb}$$

GAGE B & C:

$$\text{Equation: } .07875 M_p = G_B = \pm 350^{lb}$$

$$\therefore M_p = \frac{\pm 350}{.07875} = \underline{\underline{\pm 4440^{in\cdot lb}}}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.10-0 CALIBRATION10-1 GAGE EQUATIONS FOR CALIBRATION10-1-2 GAGE EQUATIONS & MAX. APPLIED LOADS.MAX. & MIN. LOADS APPLICABLE ON THE SYSTEM TO REACH
RATED GAGE LOADS - CONT'D.ROLLING MOMENT MR.GAGE B & C ONLY.

Equation: $\pm .130 MR = G$

$$\therefore \frac{350}{\pm .130} = \underline{\underline{\pm 2690 \text{ in/lb.}}}$$

SUMMARY-

The max. and min. loads and moments that can be applied on the system must not exceed those which will produce the rated load of the weaker gage. Thus, gage B & C are limiting these loads and moments to the values underlined in the text and summarized below:

F: Fore/aft: $\pm 150 \text{ lb}$
 Y: Side: $\pm 50 \text{ lb}$
 N: up: 1275 lb Down: -1925 lb
 Mp: Pitching M: $\pm 4440 \text{ in/lb}$
 MR: Rolling M: $\pm 2690 \text{ in/lb}$

NOTE: F & Y are limited by design consideration rather than gage strength.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.10 - 0 CALIBRATION10 - 1 GAGE EQUATIONS FOR CALIBRATION.10-1-2 GAGE EQUATIONS & MAX. APPLIED LOADSGAGE EQUATIONS IN TERMS OF F-Y-N-MP & MR FOR $\alpha = 0$

Under calibration loads, F , Y , N and $\alpha = 0$ then eq. given in 10-1-1 become:

GAGE A

$$-800 \leq -.35(N+W) \stackrel{N \geq 2.278W}{\rightarrow} -.76 F \quad -.1575 M_P \leq 800 \quad (\text{rod disengaged})$$

$$-800 \leq -.196 N \stackrel{N \leq 2.278W}{\rightarrow} -.76 F \quad -.1575 M_P \leq 800 \quad (\text{rod engaged})$$

GAGE B & C

$$-350 \leq -.325(N+W) \stackrel{N \geq 2.278W}{\rightarrow} +.38 F \quad \pm .626 Y \quad +.07875 M_P \pm .130 M_R \leq 350 \quad (\text{rod disengaged})$$

$$-350 \leq -.182 N \stackrel{N \leq 2.278W}{\rightarrow} +.38 F \quad \pm .626 Y \quad +.07875 M_P \pm .130 M_R \leq 350 \quad (\text{rod engaged})$$

GAGE D

$$-150 \leq F \leq 150$$

MAX VALUES OF APPLIED LOADS & MOMENTS

| | |
|----------------------|---|
| F - FORE/AFT | $\pm 150 \text{ lb}$ |
| Y - SIDE | $\pm 50 \text{ lb}$ |
| N - UP/DOWN | $+ 1275 \text{ lb}$ to -1925 lb |
| M_P - PITCHING MT. | $\pm 4440 \text{ in/lb}$ |
| M_R - ROLLING MT. | $\pm 2690 \text{ in/lb}$ |

NOTE: 1- Above loads (max.) apply singly when all other loads = 0

2- N may be sum of: normal load, pressure and suction load.

3- Gage readings will not differentiate between rolling Mt due to Y and M_R .

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL10-0 CALIBRATION10-1 GAGE EQUATIONS FOR CALIBRATION10-1-2 GAGE EQUATIONS & MAX. APPLIED LOADSGAGE EQUATIONS & LIMITS - ASSUMING $W = -200$ GAGE A

$$-800 \leq -0.35(N-200) \left/ \begin{array}{l} N=1275 \\ N=456 \end{array} \right. -0.76 F \left/ \begin{array}{l} F=+150 \\ F=-150 \end{array} \right. -0.1575 M_P \left/ \begin{array}{l} M_P=+4440 \\ M_P=-4440 \end{array} \right. \leq 800$$

$$-800 \leq -0.196 N \left/ \begin{array}{l} N=456 \\ N=-1925 \end{array} \right. -0.76 F \left/ \begin{array}{l} F=+150 \\ F=-150 \end{array} \right. -0.1575 M_P \left/ \begin{array}{l} M_P=+4440 \\ M_P=-4440 \end{array} \right. \leq 800$$

GAGE B & C

$$-350 \leq -0.325(N-200) \left/ \begin{array}{l} N=1275 \\ N=456 \end{array} \right. +0.38 F \left/ \begin{array}{l} F=+150 \\ F=-150 \end{array} \right. \mp 0.626 Y \left/ \begin{array}{l} Y=+50 \\ Y=-50 \end{array} \right. +0.07875 M_P \left/ \begin{array}{l} M_P=+4440 \\ M_P=-4440 \end{array} \right.$$

$$\pm 0.13 M_R \left/ \begin{array}{l} M_R=+2690 \\ M_R=-2690 \end{array} \right. \leq 350$$

$$-350 \leq -0.182 N \left/ \begin{array}{l} N=456 \\ N=-1925 \end{array} \right. +0.38 F \left/ \begin{array}{l} F=+150 \\ F=-150 \end{array} \right. \mp 0.626 Y \left/ \begin{array}{l} Y=+50 \\ Y=-50 \end{array} \right. +0.07875 M_P \left/ \begin{array}{l} M_P=+4440 \\ M_P=-4440 \end{array} \right.$$

$$\pm 0.13 M_R \left/ \begin{array}{l} M_R=+2690 \\ M_R=-2690 \end{array} \right. \leq 350$$

GAGE D

$$-150 \leq F \left/ \begin{array}{l} F=+150 \\ F=-150 \end{array} \right. \leq 150$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL10-0 CALIBRATION10-2-0 CALIBRATION PROCEDURE.

The equations on page give the relations between gage loading and the applied loads N, F & Y and the moments M_P & M_R . These equations will hold only when there is no other interaction between the gages. The purpose of calibration is to find out any such interaction which may exist and provide means of adjusting these equations accordingly.

The calibration tests will be carried out in 4 series:

- Series 1 - Each load or moment applied singly.
- Series 2 - Loads N, F & moment M_P in combinations
- Series 3 - Loads N, F, Y & moments M_P & M_R in combinations
- Series 4 - Cases representing expected loading as calculated in the stress analysis report.

SERIES 1 - Each load or moment applied singly

Table 1 & 2 indicate the loads to be applied on the calibration rig. These loads should be applied in steps from 0 to max. to 0 and from 0 to min. to 0.

SERIES 2 & 3 Combined loading.

The general principle used for calibrating under combined loading is a system where the gage load is held at a definite value and the applied loads and moments adjusted in various combinations to produce the same gage load. Thus, by using values of the applied loads and moments which should theoretically give a chosen gage load, it will be possible to estimate the error on the

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -10-0 CALIBRATION10-2-0 CALIBRATION PROCEDURE - CONT'D.

gauge reading at various gauge loading level. A minimum of 5 different combinations should be tested at each gauge level for both 2 or more applied loads or moments combinations.

Series 2 - All possible combinations of N, F & M_P are shown graphically on charts 3 & 4 for gauge A and on charts 5 & 6 for gauges B & C.

Series 3 - All possible combinations of $N, F, Y,$ M_P & M_R are shown graphically on charts 7 & 8 for gauges B & C.

It should be noted that gauge A is not theoretically affected by Y or M_R . However, it will be necessary to observe its reading during calibration of gauges B & C.

SERIES 4 - Straining Cases.

This series is an attempt to represent approximately the conditions of the model tests. It is felt that this series of calibration tests will give some information on the behaviour of the balance in a range close to that we may expect in operation. Loads to be applied on the calibration rig for each cases stressed in this report are given on table 3.

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STRESS ANALYSIS OF $\frac{1}{2}$ SCALE HOVERING & TRANSITION MODEL

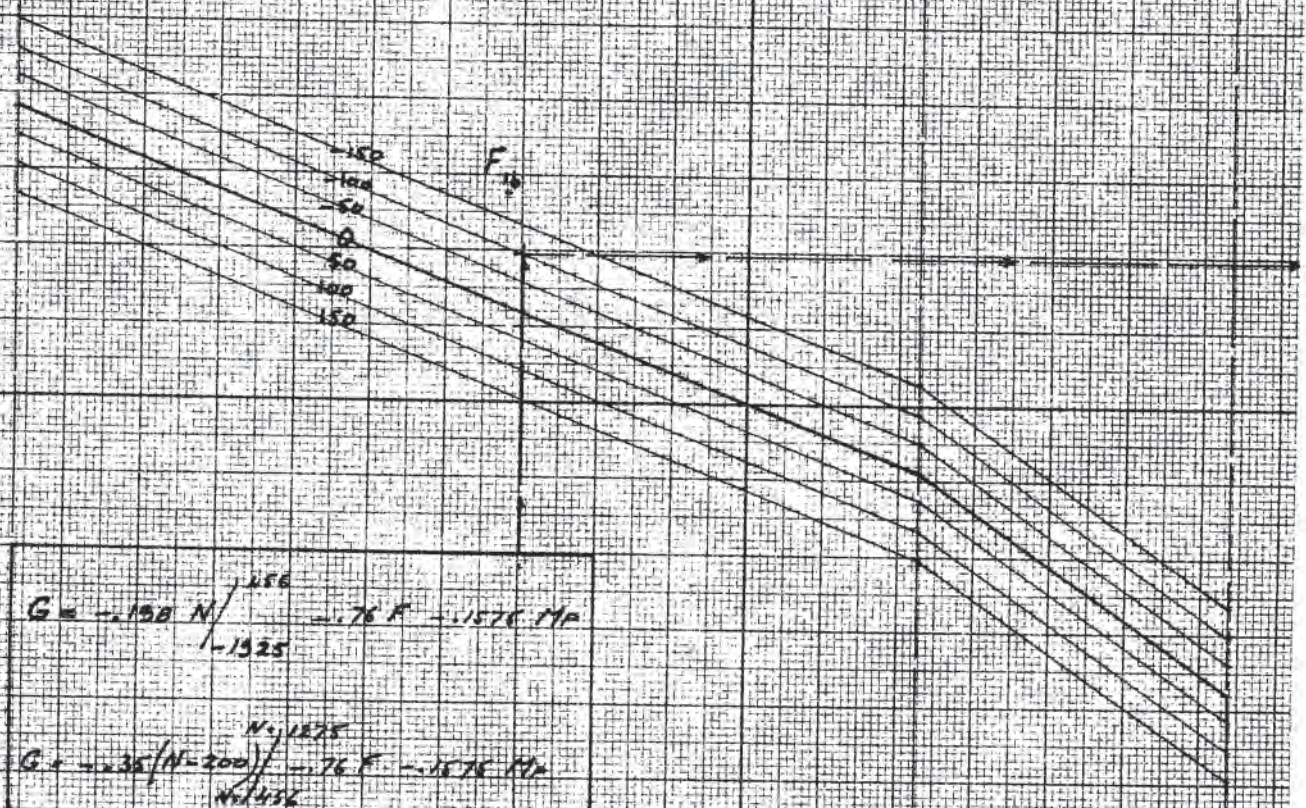
GAGE CALIBRATION

10-0 CALIBRATION

10-1 GAGE EQUATIONS FOR CALIBRATION

GRAPHICAL SOLUTION

10-1-2 GAGE EQUATIONS & MAX. APPLIED LOADS



-1325

$N/1000$

0

156

1275

EXAMPLE $N = 600 \text{ lb}$ $F = -100 \text{ lb}$ $M_p = 2000 \text{ in/lb}$

THUS GAGE A: 510 lb TENSION

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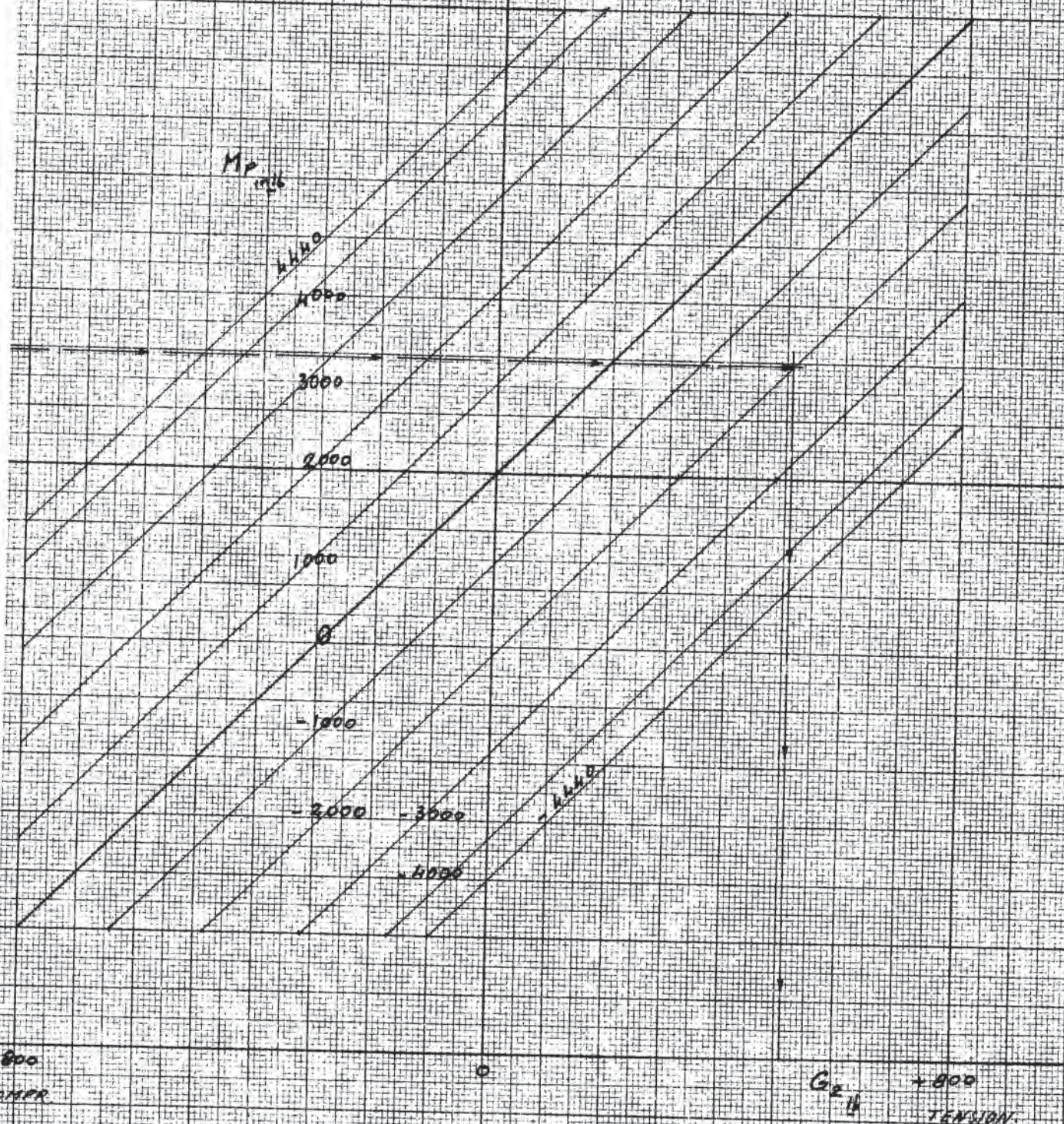
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ATIONS

GAGE - A -

CHART No 1



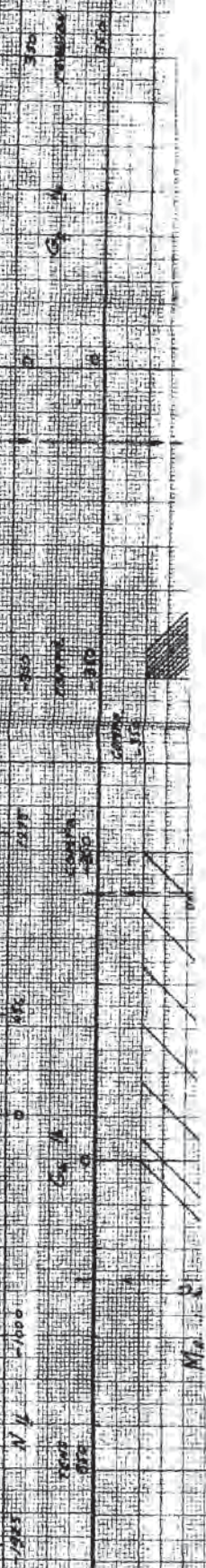
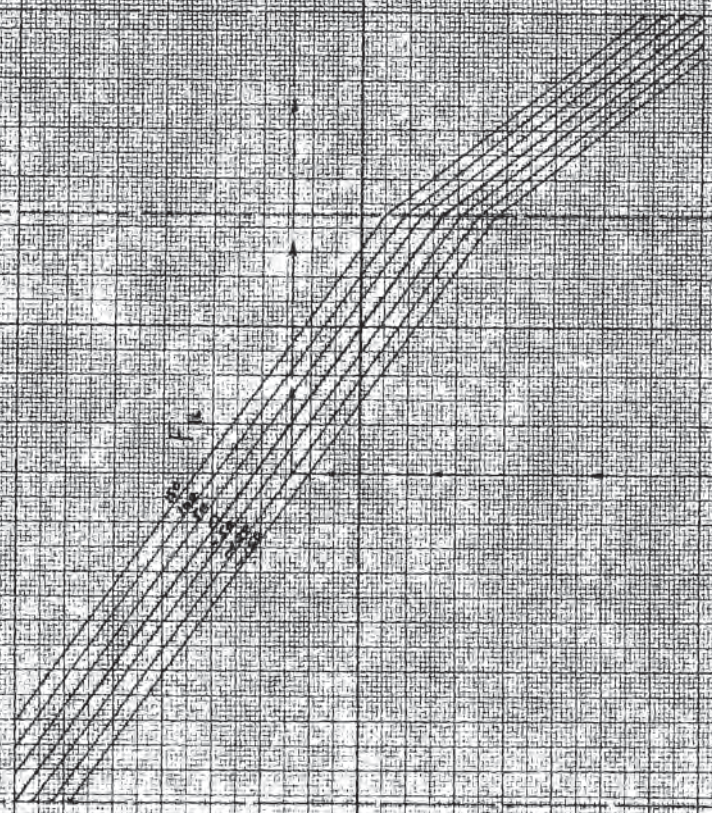
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STRESS ANALYSIS OF 15 KEVLE HANDBOOK 4 TRANSDUCER
WCPAN
10-0 CALIBRATION
10-1 GAGE EQUATIONS FOR CALIBRATION
10-2 GAGE EQUATIONS OF TWO GAGE PAIRS

GAGE CALIBRATION EQUATIONS
GRAPHICAL SOLUTION

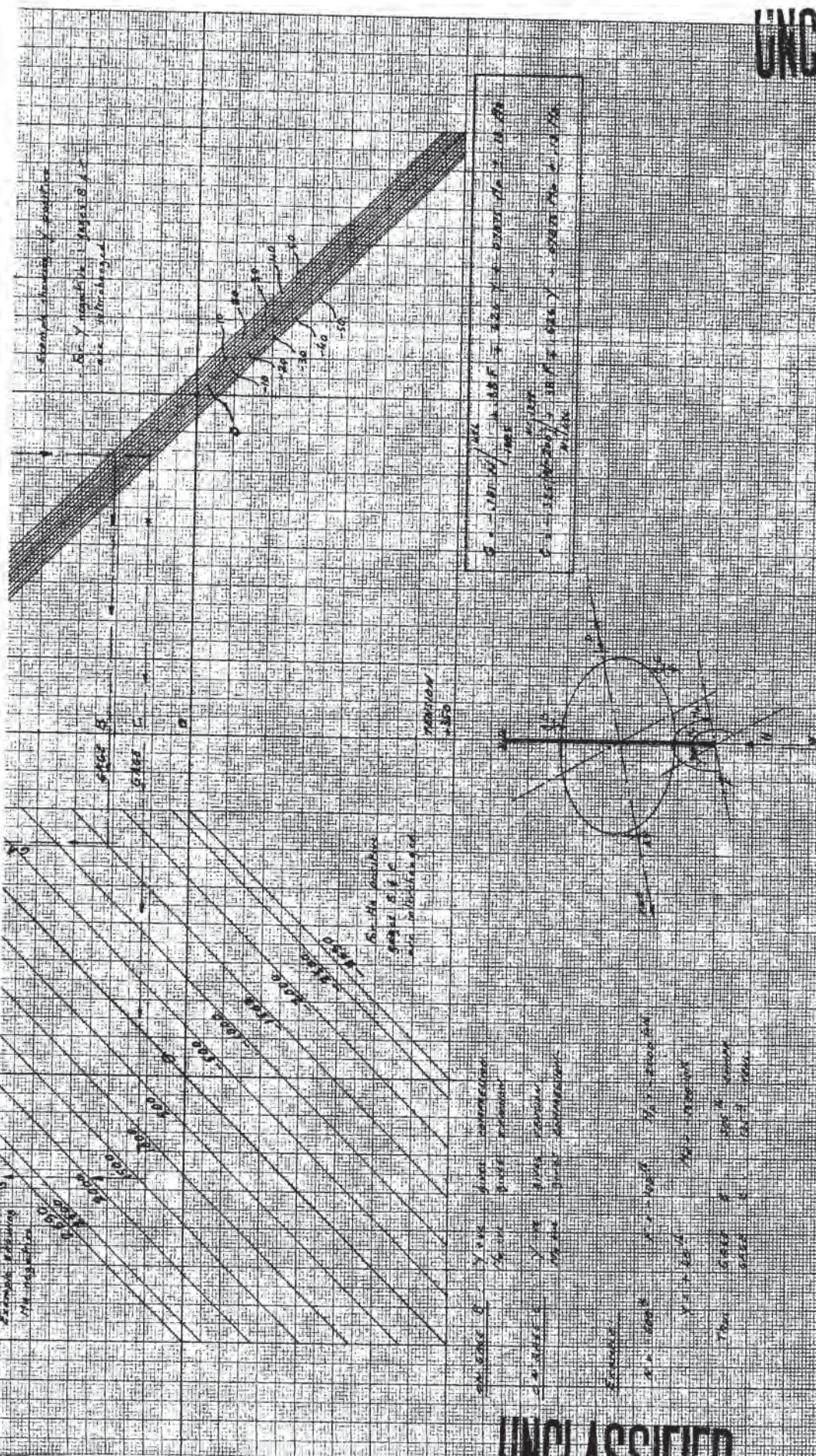
GAGES B & C CHART N° 2

$G_1 = 1/4$
TENSION
+300



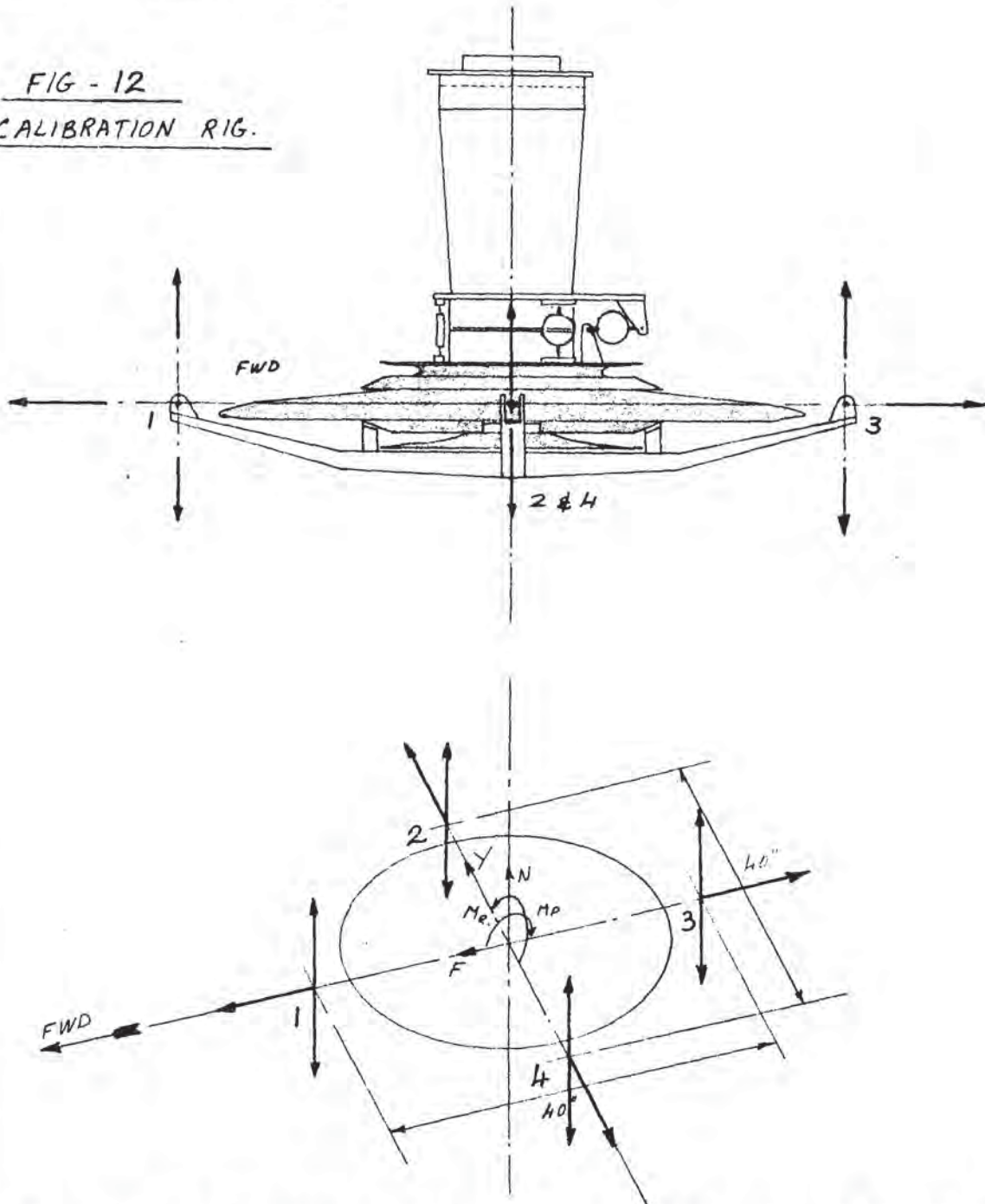
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL10-0 CALIBRATION10-2 CALIBRATION RIG.10-2-1 DESCRIPTION.FIG - 12
CALIBRATION RIG.

AT EACH POINT 1, 2, 3 & 4, WE MAY HAVE AN OUT BOARD LOAD, AN UP LOAD, A DOWN LOAD OR A COMBINATION OF THE THREE.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL10-0 CALIBRATION10-2 CALIBRATION RIG10-2-2 LOADS ON CALIBRATION RIGTABLE 1DISTRIBUTION OF LOADS & MOMENTS ON LOADING POINTS-

| LOAD | 1 | | | 2 | | | 3 | | | 4 | | |
|--|-----|------------------|------------------|-----|------------------|------------------|-----|------------------|------------------|-----|------------------|------------------|
| | OUT | UP | DOWN | OUT | UP | DOWN | OUT | UP | DOWN | OUT | UP | DOWN |
| $F / \begin{smallmatrix} 150 \\ 0 \\ -150 \end{smallmatrix}$ | F | | | | | | F | | | | | |
| $Y / \begin{smallmatrix} 50 \\ 0 \\ -50 \end{smallmatrix}$ | | | | Y | | | | | | Y | | |
| $N / \begin{smallmatrix} 1275 \\ 0 \\ -1275 \end{smallmatrix}$ | | $\frac{N}{4}$ | $\frac{N}{4}$ | | $\frac{N}{4}$ | $\frac{N}{4}$ | | $\frac{N}{4}$ | $\frac{N}{4}$ | | $\frac{N}{4}$ | $\frac{N}{4}$ |
| $M_R / \begin{smallmatrix} 2690 \\ 0 \\ -2690 \end{smallmatrix}$ | | | | | $\frac{M_R}{40}$ | $\frac{M_R}{40}$ | | | | | $\frac{M_R}{40}$ | $\frac{M_R}{40}$ |
| $M_P / \begin{smallmatrix} 4440 \\ 0 \\ -4440 \end{smallmatrix}$ | | $\frac{M_P}{40}$ | $\frac{M_P}{40}$ | | | | | $\frac{M_P}{40}$ | $\frac{M_P}{40}$ | | | |

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL10-0 CALIBRATION10-2 CALIBRATION RIG10-2-2 LOADS ON CALIBRATION RIG.TABLE 2SIMPLE CASE - ONE LOAD ALONE -

ALL LOADS IN lb

| LOAD | 1 | | | 2 | | | 3 | | | 4 | | |
|---|-----|-------|--------|-----|-------|--------|-----|-------|--------|-----|-------|--------|
| | OUT | UP | DOWN | OUT | UP | DOWN | OUT | UP | DOWN | OUT | UP | DOWN |
| F=150 F=-150 | 150 | | | | | | 150 | | | | | |
| Y=50 Y=-50 | | | | 50 | | | | | | 50 | | |
| N=1275 N=-1925 | | 318.5 | | | 318.5 | | | 318.5 | | | 318.5 | |
| | | | 481.25 | | | 481.25 | | | 481.25 | | | 481.25 |
| M _R = 2690 ^{inlb} M _R = -2690 ^{inlb} | | | | | | 67.25 | | | | | 67.25 | |
| | | | | | 67.25 | | | | | | | 67.25 |
| M _P = 4440 ^{inlb} M _P = -4440 ^{inlb} | | /// | | | | | | | /// | | | |
| | | | /// | | | | | /// | | | | |

ABOVE LOAD F WILL BRING GAGE D TO ITS RATED LOAD.

ABOVE LOAD N WILL BRING GAGE B & C TO THEIR RATED LOADS.

ABOVE M_T M_R " " " " " " " "ABOVE M_T M_P " " " " " " " "

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

10-0 CALIBRATION

10-2 CALIBRATION RIG.

10-2-2 LOADS ON CALIBRATION RIG.

TABLE 3

TEST CASES WITH NO ROLLING MOMENT OR SIDE LOAD.

| LOADS ON RIG | | | | | 1 | | | 2 | | | 3 | | | 4 | | |
|------------------------------|--|--|--|--|-----------------|-----------------|-------------------------|------|--------|-------|-----|----|-------|-----|----|-------|
| APPLIED LOADS | | | | | N _{1b} | F _{1b} | M _p in lb | OUT | UP | DOWN | OUT | UP | DOWN | OUT | UP | DOWN |
| CASE | | | | | | | | | | | | | | | | |
| HOVERING HORIZONTAL | | | | | 16.4 | 0 | 0 | | | 41 | | | 41 | | | 41 |
| HOVERING 20° | | | | | -189.5 | -3.8 | -85.3 | | | 68.3 | | | 47.1 | 3.8 | | 47.1 |
| HIGH DRAG | | | | | -189.8 | -10.2 | -144.0 | | | 83.4 | | | 47.4 | | | 47.4 |
| MAX. THRUST | | | | | -486 | +141 | 0 | 141 | | 121.5 | | | 121.5 | | | 121.5 |
| TRANSITION -10° 30 PSF | | | | | -546 | +29.2 | -4320 | 29.2 | | 244.5 | | | 136.5 | | | 136.5 |
| TRANSITION 20° 30 PSF | | | | | -30.2 | -27 | +1535 | | 30.85 | | | | 7.55 | 27 | | 7.55 |
| TRANSITION 35° 30 PSF | | | | | +156 | +21.2 | +2735 | 21.2 | 107.4 | | | 39 | | | 39 | |
| TRANSITION 45° 18 PSF | | | | | -21 | -38 | +4320 | | 102.75 | | | | 5.25 | 38 | | 5.25 |

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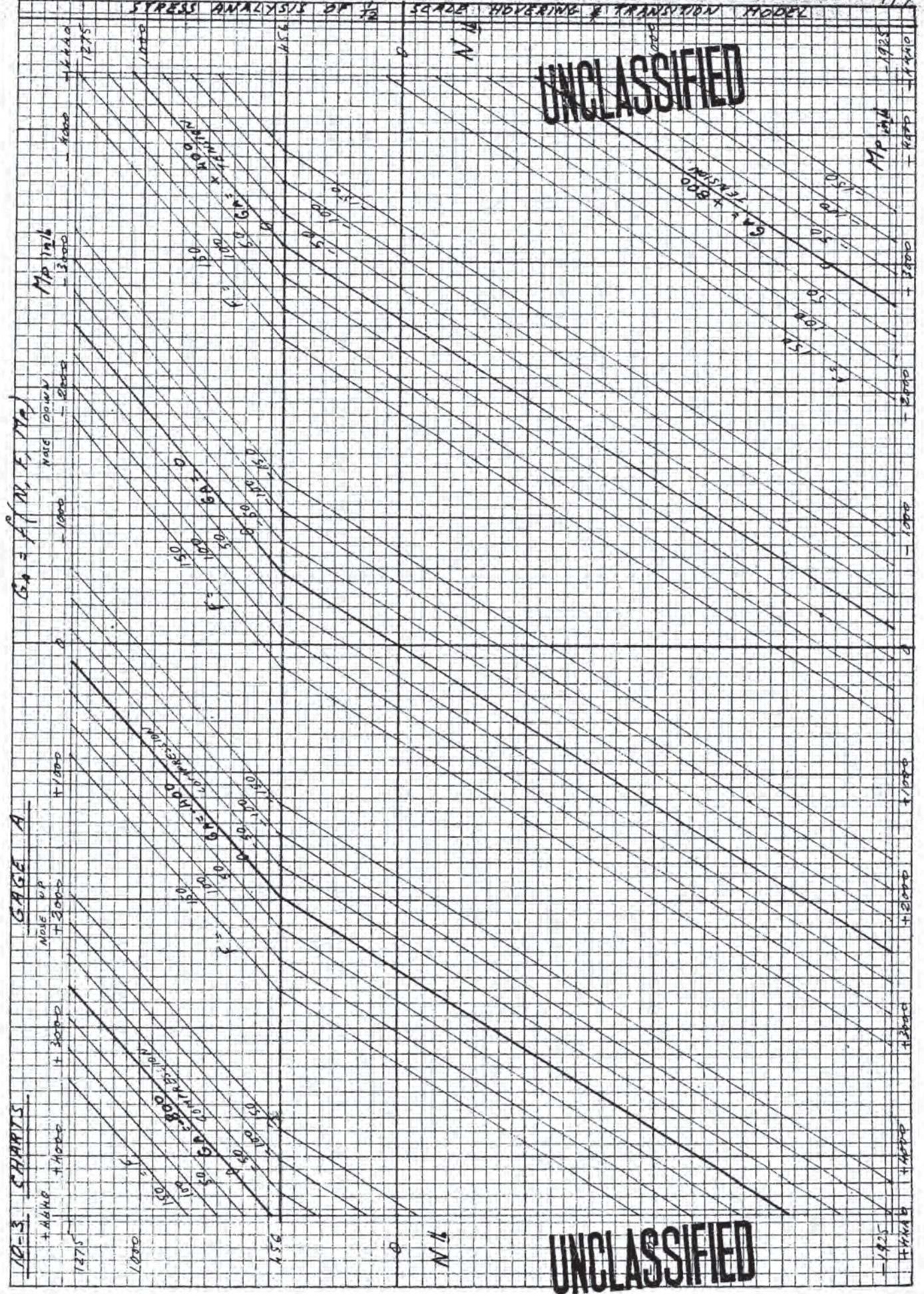
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CHART N°3



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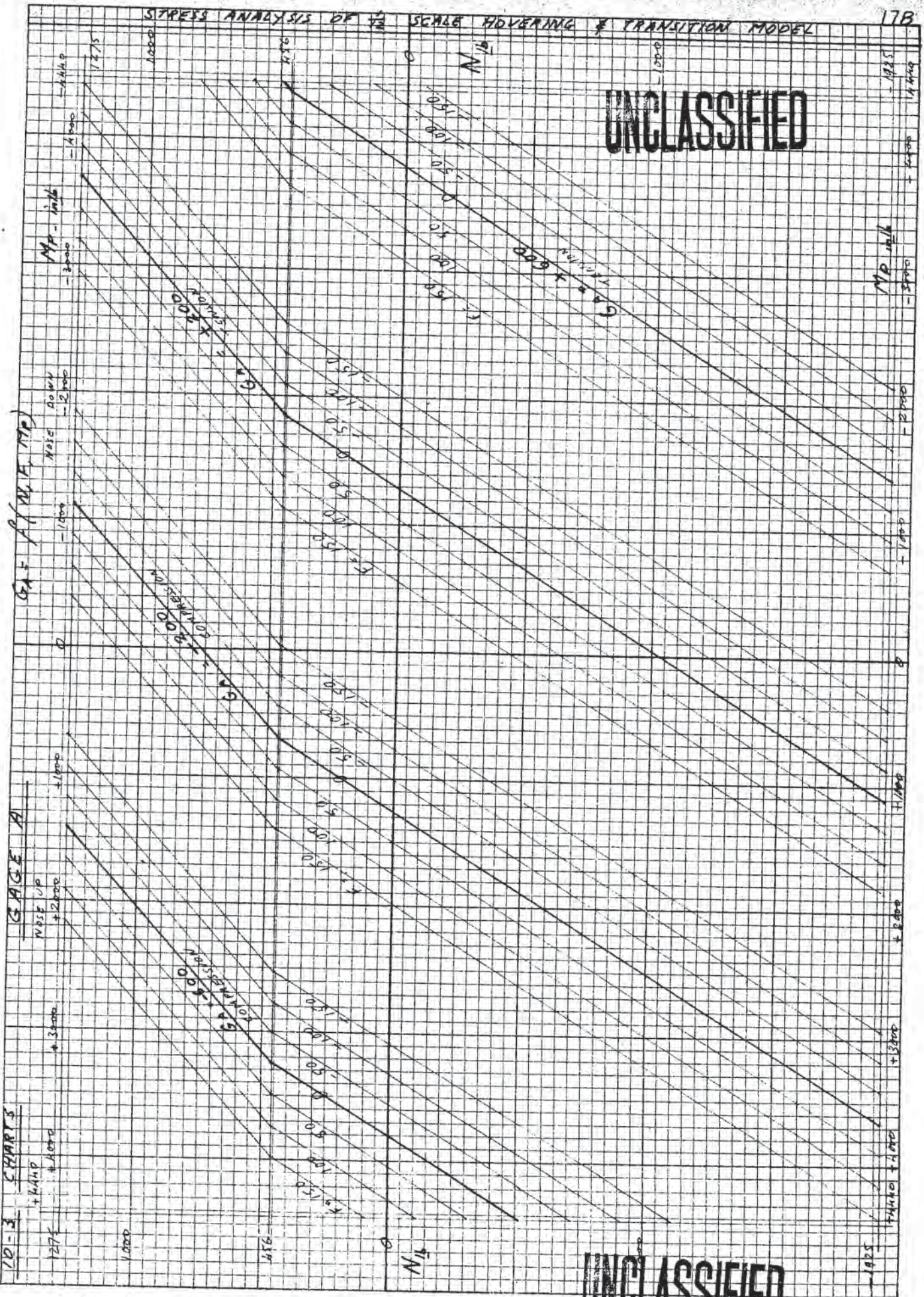
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10 X 10 to the inch
KENTLER & ESSER CO.

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CHART N° 4



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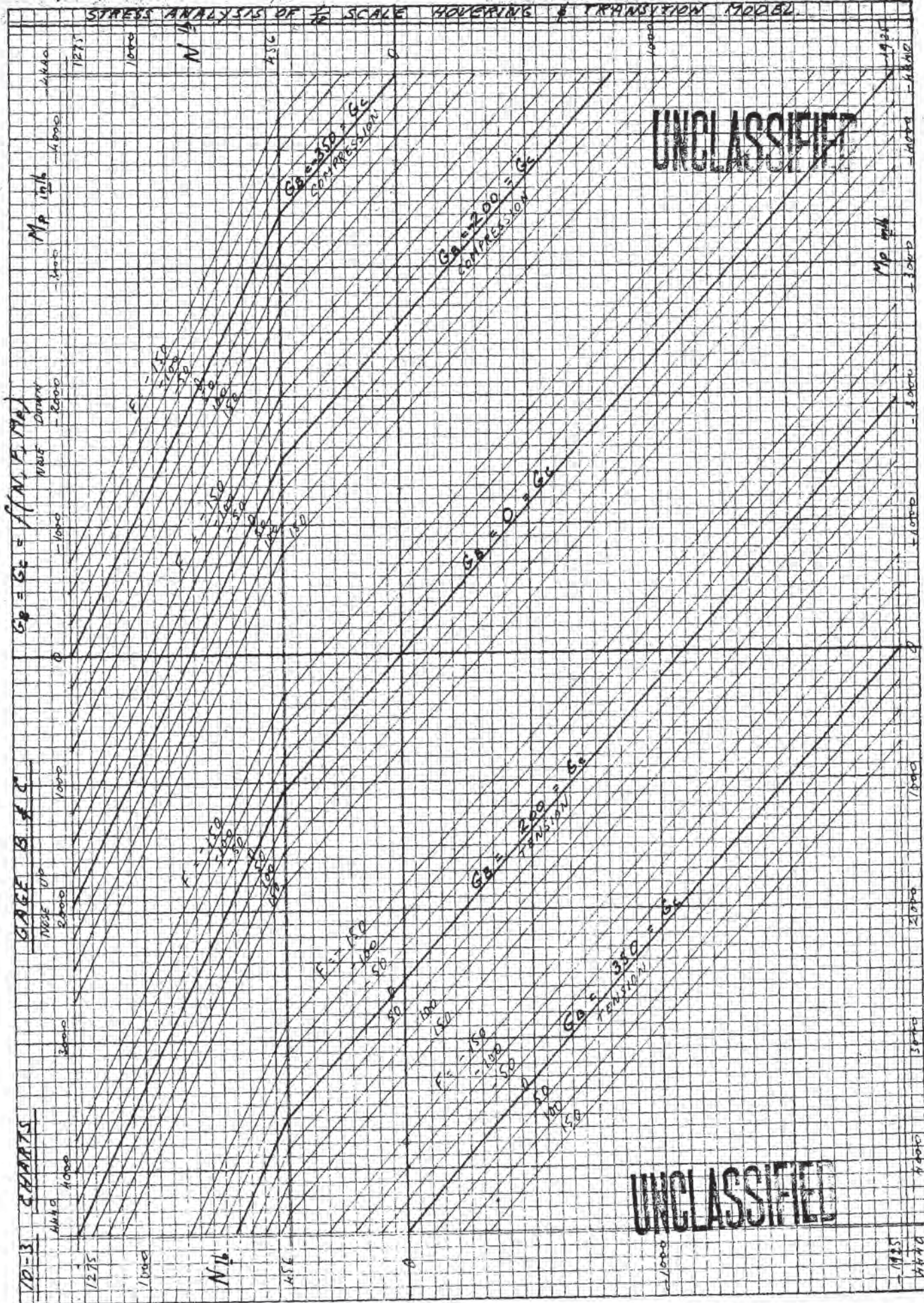


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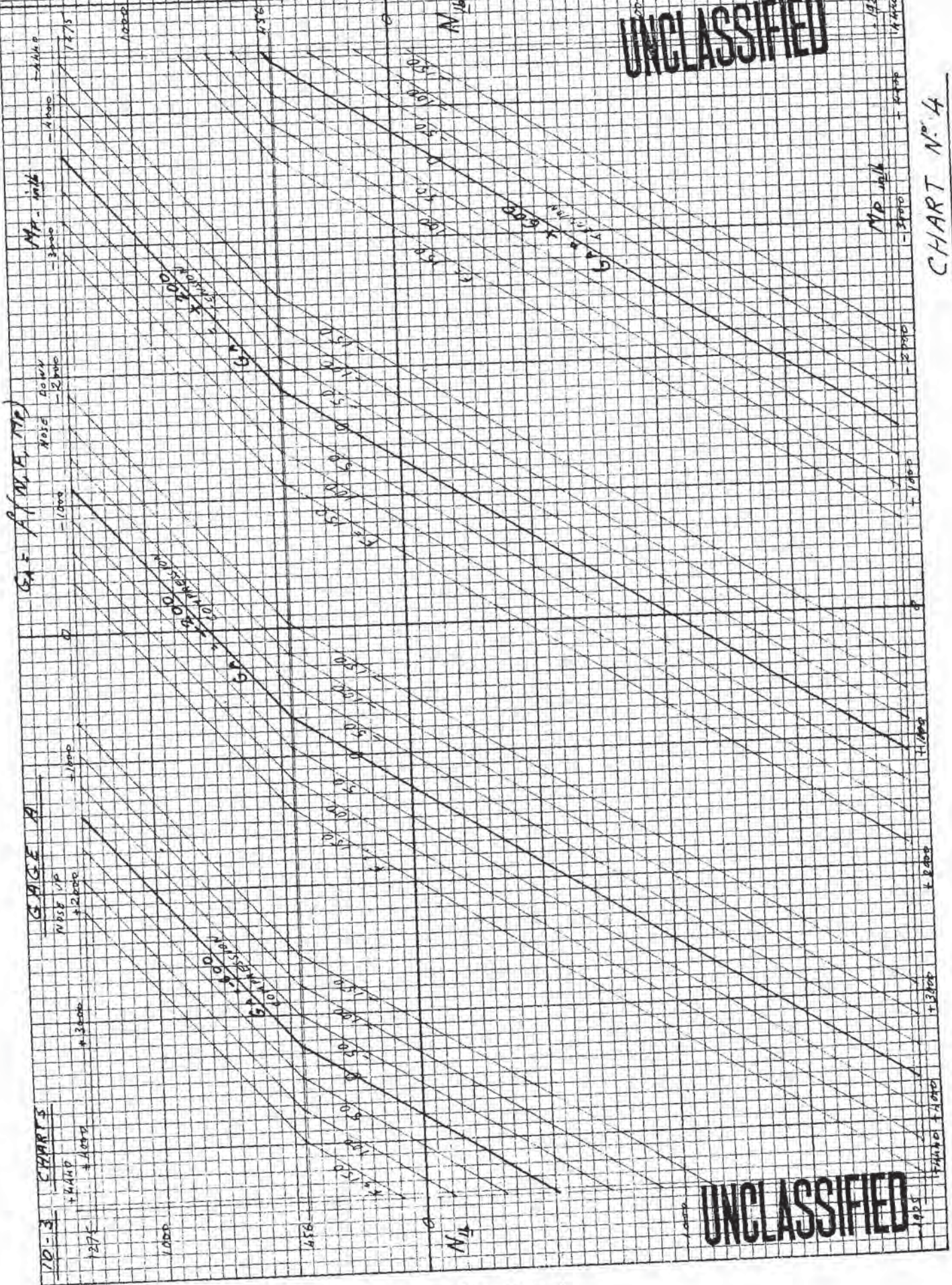
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CHART N° 4



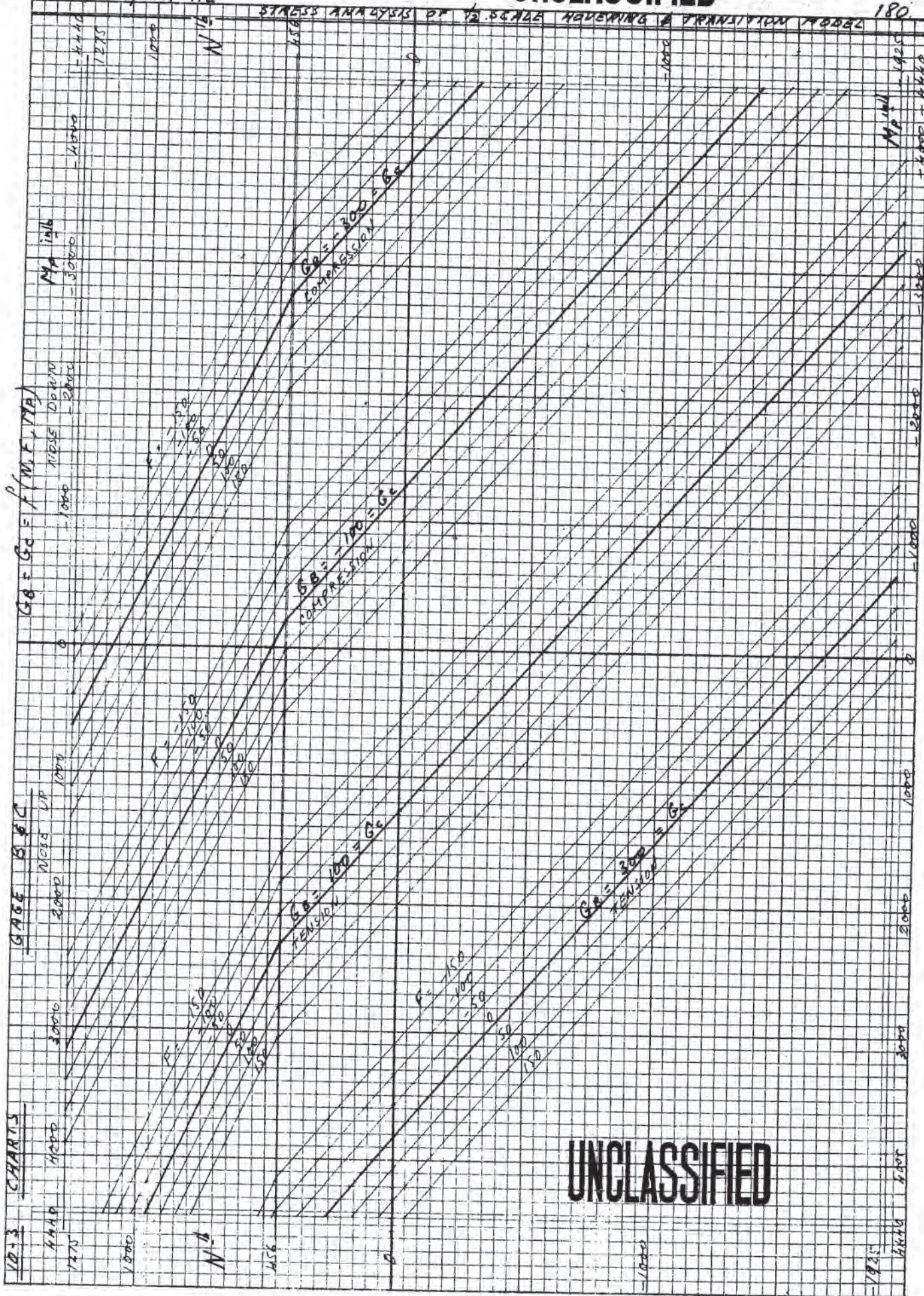
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CHART N°6



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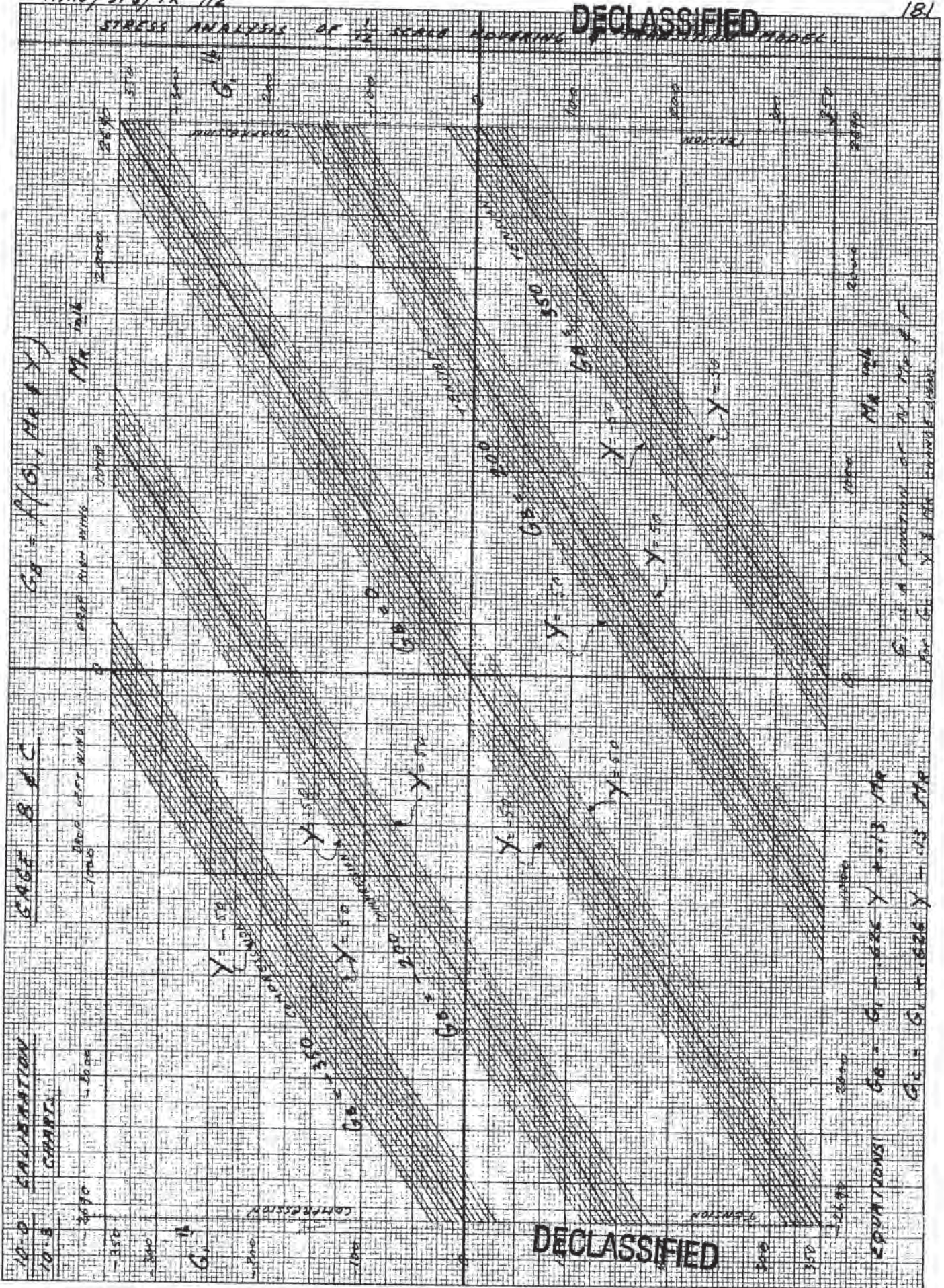
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CHART No. 7



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STRESS ANALYSIS OF $\frac{1}{4}$ SCALE ROVERING & TRANSITION MODEL

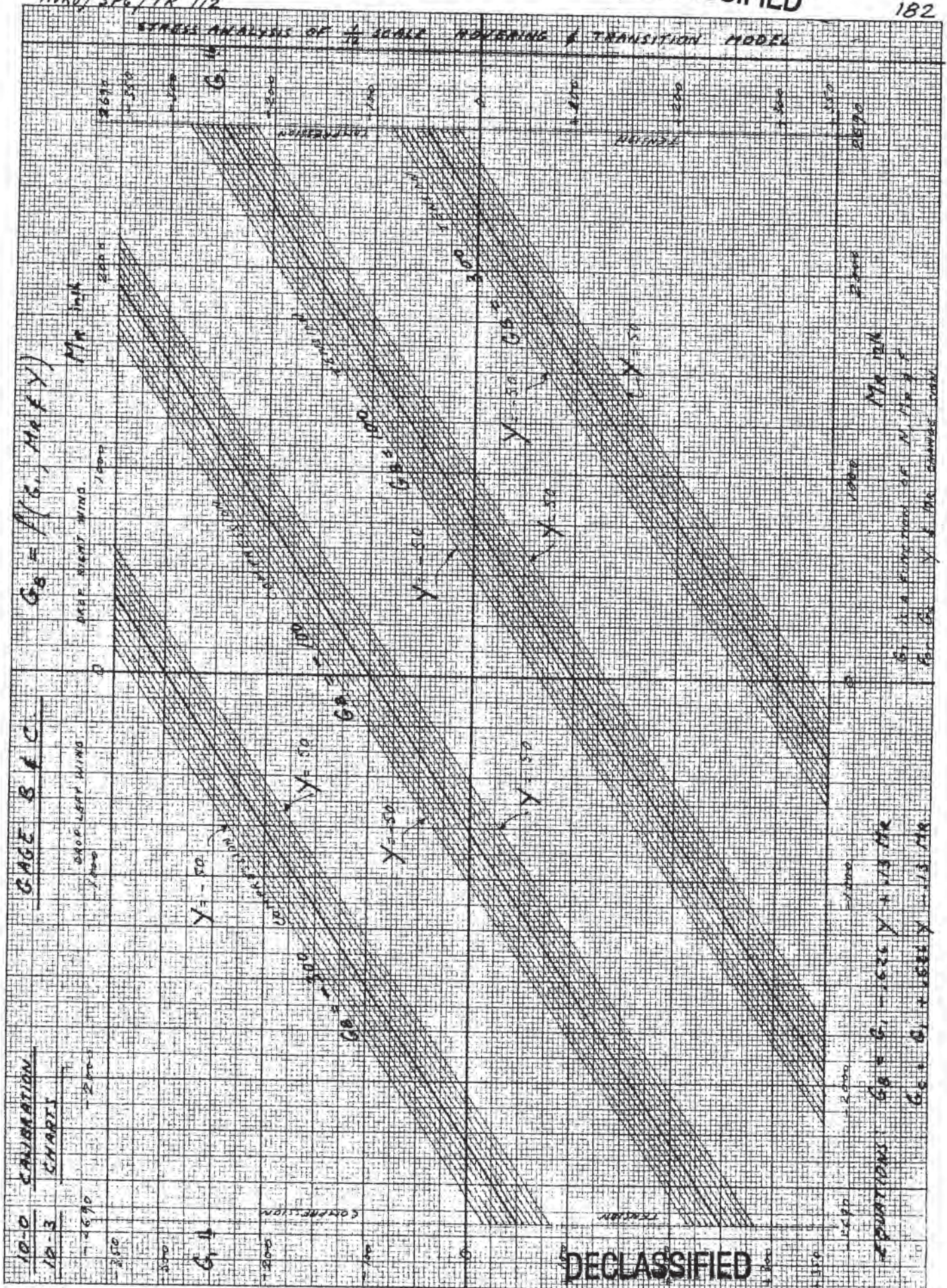


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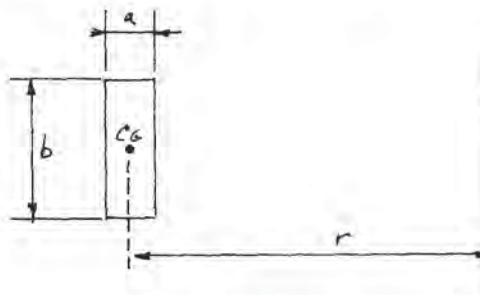
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELAPPENDIX A - CALCULATION OF WEIGHT.A-1 - WEIGHT OF MODELA-1-1 GENERAL.

Volume of an annulus: Sectional area \times path of the CG.

$$V = a b 2\pi r$$

$$W = \rho a b 2\pi r$$



Using Simpson's rule we can fix

$$a = .25''$$

$$\rho = .283 \frac{\text{lb}}{\text{in}^3}$$

hence: the term $2\pi a \rho = 2 \times \pi \times .25 \times .283 = .445$

Hence: the weight of one element: $dW = .445 b r$

and the total weight of one annular part is

$$W = .445 \Sigma b r$$

Values of $b r$ are tabulated for each part.

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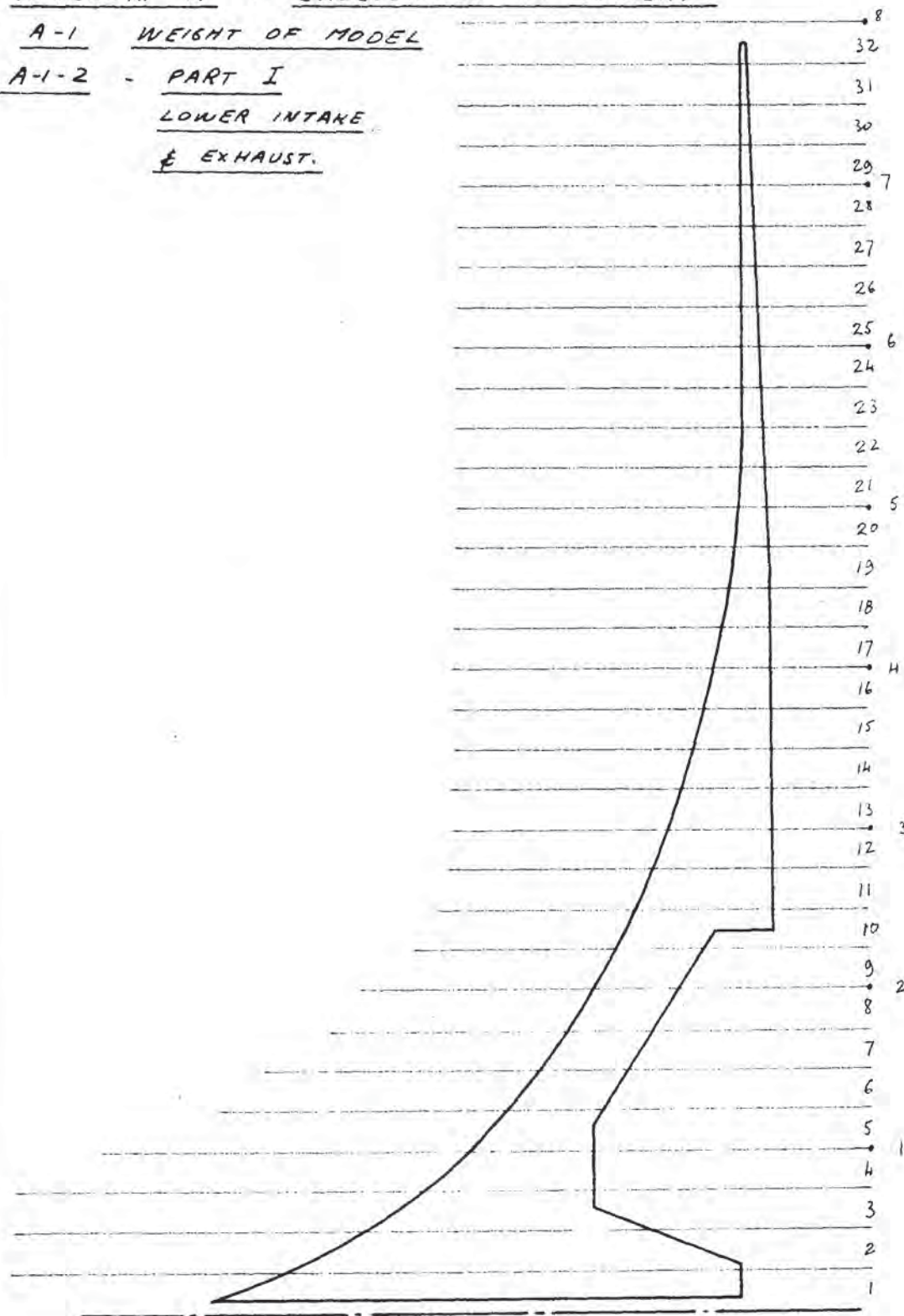
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.APPENDIX A - CALCULATION OF WEIGHTA-1 WEIGHT OF MODELA-1-2 - PART ILOWER INTAKE& EXHAUST.

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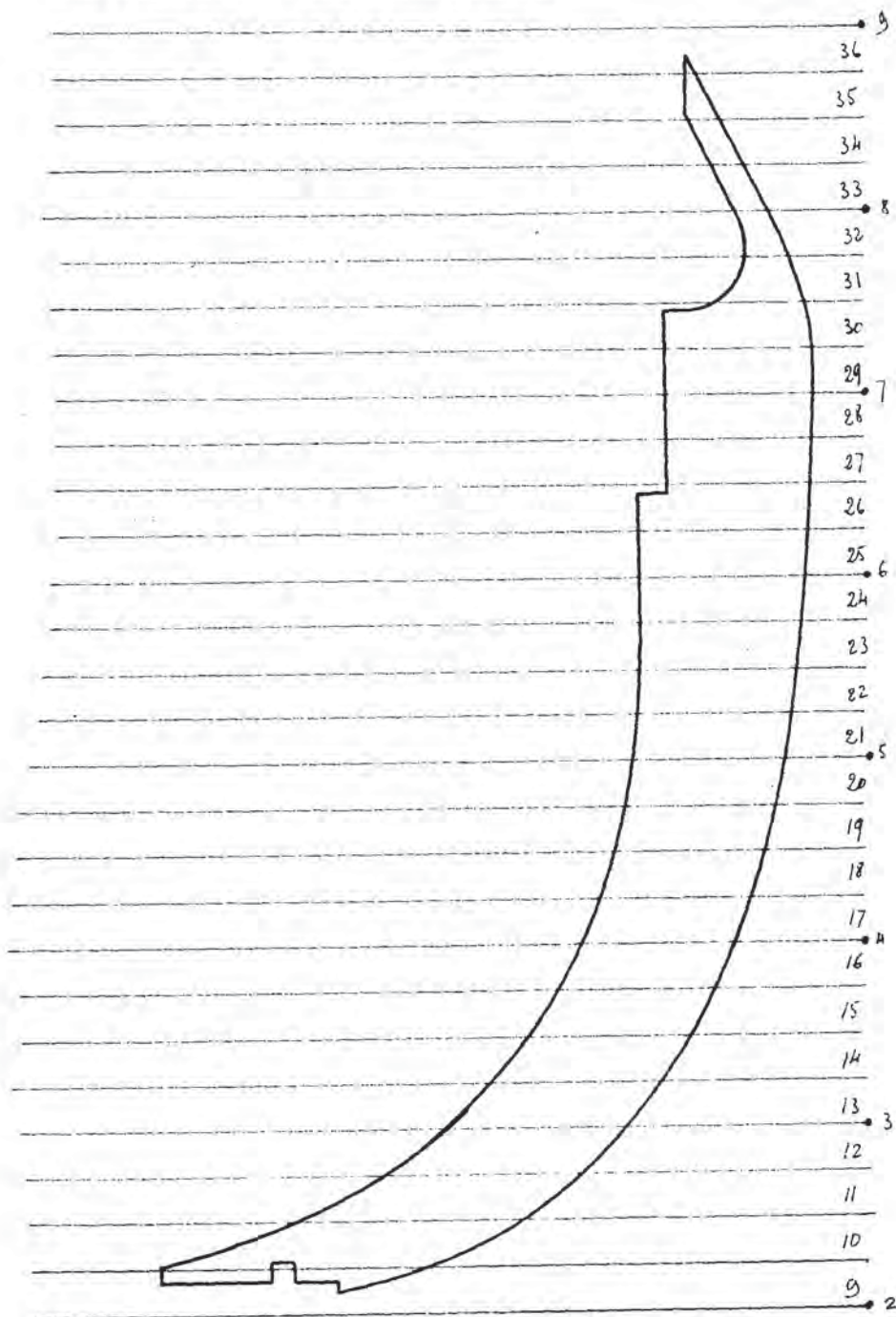
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

APPENDIX A - CALCULATION OF WEIGHT

A-1 WEIGHT OF MODEL

A-1-3 PART II LOWER RAMP.



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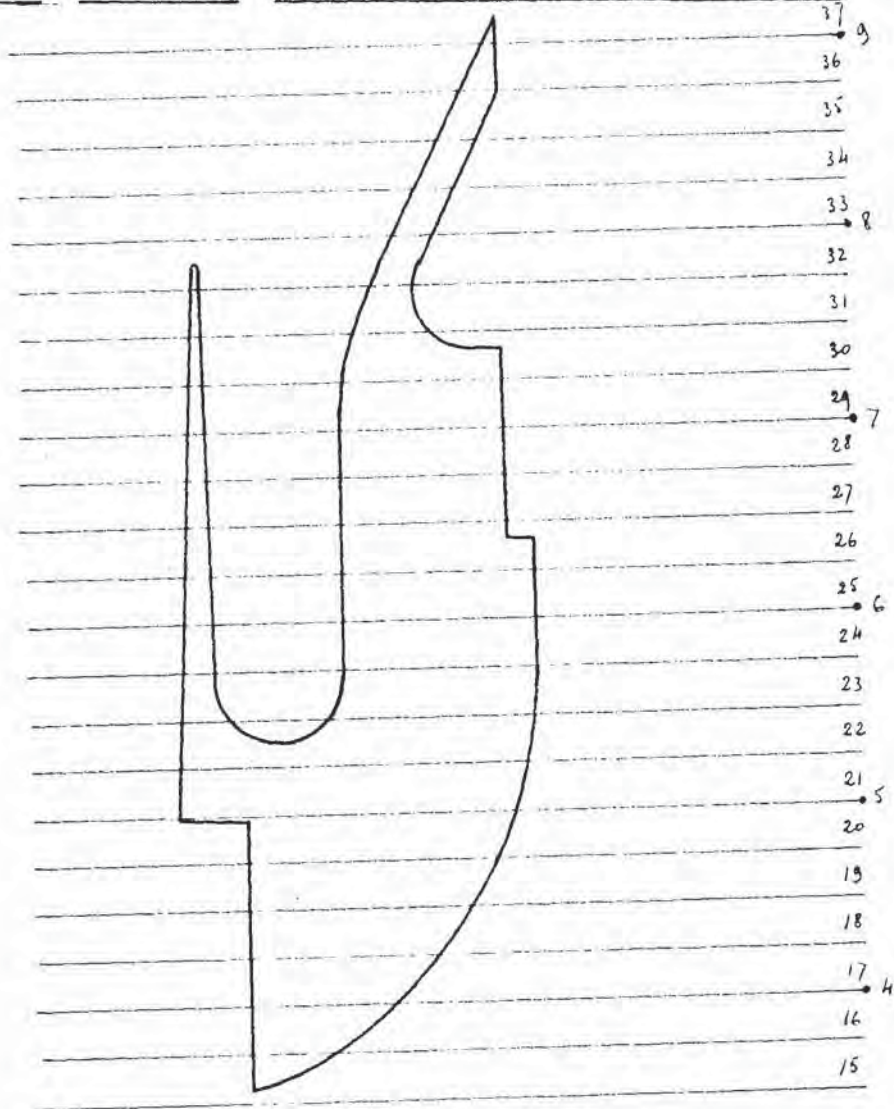
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

APPENDIX A - CALCULATION OF WEIGHT

A-1 WEIGHT OF MODEL

A-1-4 PART III UPPER FALSE INTAKE & RAMP.



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STRESS ANALYSIS OF $\frac{1}{8}$ SCALE HOVERING MODEL

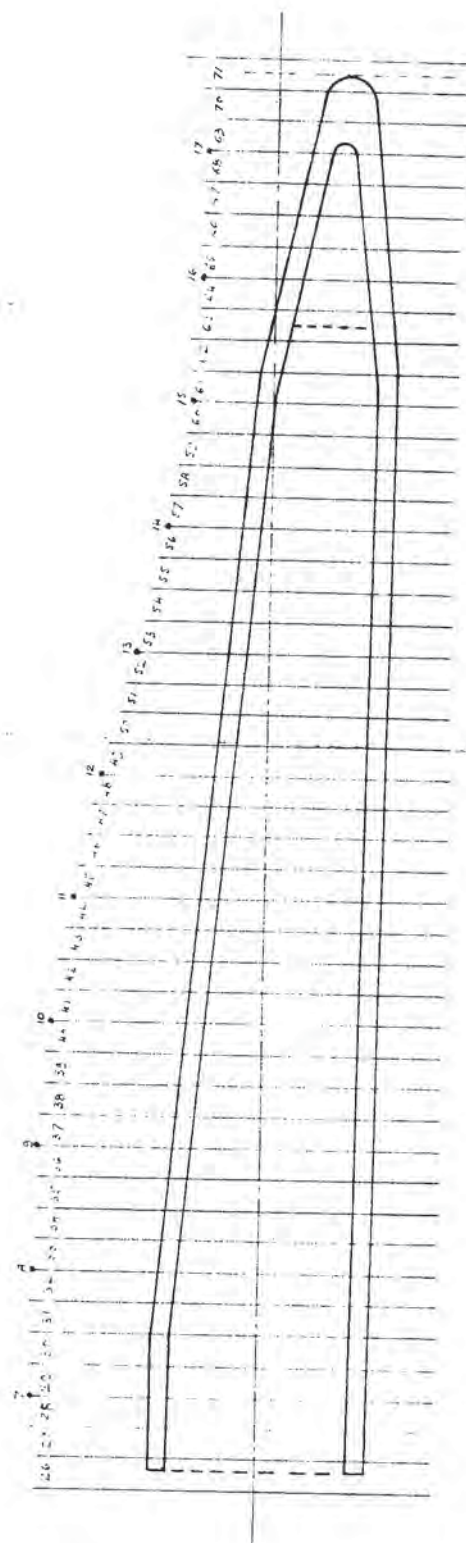
APPENDIX A - CALCULATION OF WEIGHT

A-1 WEIGHT OF MODEL

A-1-S PART II - WING

S. J. J. J. J.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL
4-1-5 WEIGHT OF MODEL COMPONENTS.

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| ITEM | PART I | | | PART II | | | PART III | | | SECRET DECLASSIFIED |
|------|---------|---------|----------------------|---------|---------|----------------------|----------|---------|----------------------|------------------------|
| | r | b | rb | r | b | rb | r | b | rb | |
| | in a | in b | in ² c | in d | in e | in ² f | in g | in h | in ² i | |
| 1 | .125 | .31 | .3875 | | | | | | | |
| 2 | .375 | .23 | .8625 | | | | | | | |
| 3 | .625 | .13 | .8125 | | | | | | | |
| 4 | .875 | .10 | .7875 | | | | | | | |
| 5 | 1.125 | .04 | .7200 | | | | | | | |
| 6 | 1.375 | .56 | .7700 | | | | | | | |
| 7 | 1.625 | .50 | .8125 | | | | | | | |
| 8 | 1.875 | .51 | .9560 | | | | | | | |
| 9 | 2.125 | .53 | 1.1280 | 2.125 | .30 | .6380 | | | | |
| 10 | 2.375 | .73 | 1.7320 | 2.375 | 1.30 | 3.0850 | | | | |
| 11 | 2.625 | .91 | 2.1250 | 2.625 | 1.10 | 2.6250 | | | | |
| 12 | 2.875 | .71 | 2.0400 | 2.875 | 1.10 | 2.7720 | | | | |
| 13 | 3.125 | .61 | 1.9050 | 3.125 | .91 | 3.0000 | | | | |
| 14 | 3.375 | .53 | 1.7710 | 3.375 | .83 | 3.0000 | | | | |
| 15 | 3.625 | .45 | 1.6220 | 3.625 | .86 | 3.1200 | 3.625 | .15 | .5440 | |
| 16 | 3.875 | .38 | 1.4705 | 3.875 | .83 | 3.2150 | 3.875 | .60 | 2.3250 | |
| 17 | 4.125 | .33 | 1.3625 | 4.125 | .82 | 3.3850 | 4.125 | .88 | 3.6350 | |
| 18 | 4.375 | .28 | 1.2250 | 4.375 | .85 | 3.5900 | 4.375 | 1.00 | 4.7650 | |
| 19 | 4.625 | .23 | 1.0625 | 4.625 | .82 | 3.7900 | 4.625 | 1.23 | 5.6900 | |
| 20 | 4.875 | .18 | .8775 | 4.875 | .85 | 4.0000 | 4.875 | 1.35 | 6.5800 | |
| 21 | 5.125 | .16 | .8200 | 5.125 | .84 | 4.3100 | 5.125 | 1.19 | 9.1800 | |
| 22 | 5.375 | .15 | .8060 | 5.375 | .75 | 4.5720 | 5.375 | 1.70 | 9.6900 | |
| 23 | 5.625 | .12 | .7320 | 5.625 | .87 | 4.8900 | 5.625 | 1.20 | 6.7500 | |
| 24 | 5.875 | .12 | .7050 | 5.875 | .89 | 5.2250 | 5.875 | 1.15 | 6.7500 | |
| 25 | 6.125 | .11 | .6740 | 6.125 | .90 | 5.6400 | 6.125 | 1.14 | 6.9800 | |
| 26 | 6.375 | .10 | .6380 | 6.375 | .93 | 5.9300 | 6.375 | 1.06 | 6.7500 | |
| 27 | 6.625 | .09 | .5960 | 6.625 | .78 | 5.1700 | 6.625 | .97 | 6.4200 | |
| 28 | 6.875 | .08 | .5500 | 6.875 | .79 | 5.4300 | 6.875 | .96 | 6.6000 | |
| 29 | 7.125 | .07 | .4980 | 7.125 | .80 | 5.7000 | 7.125 | .95 | 6.7700 | |
| 30 | 7.375 | .06 | .4425 | 7.375 | .80 | 5.9000 | 7.375 | .75 | 5.5300 | |
| 31 | 7.625 | .05 | .3810 | 7.625 | .32 | 2.4400 | 7.625 | .35 | 2.6700 | 31.3355 |
| 32 | 7.875 | | | 7.875 | .00 | 1.5750 | 7.875 | .24 | 1.8900 | 77.0215 |
| 33 | 8.125 | | | 8.125 | .10 | 1.4625 | 8.125 | .22 | 1.7850 | 106.1930 |
| 34 | 8.375 | | | 8.375 | .18 | 1.5080 | 8.375 | | | 234.5500 |
| 35 | 8.625 | | | 8.625 | .15 | .9480 | 8.625 | .22 | 1.9200 | 234.5500 |
| 36 | 8.875 | | | 8.875 | | | 8.875 | .13 | 1.1535 | 104.2100 |

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL
H-1-S WEIGHT OF MODEL COMPONENTS.

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| PART IV | | | | PART IV | | | | SECRET DECLASSIFIED | | |
|---------|--------|------|-----------------|---------|--------|------|-----------------|------------------------|---|---|
| ITEM | r | b | rb | ITEM | r | b | rb | | | |
| a | in | in | in ² | e | in | in | in ² | j | k | m |
| b | c | d | f | g | h | | | | | |
| 1 26 | 6.460 | .300 | 1.938 | 56 | 12.875 | .300 | 4.165 | | | |
| 2 27 | 7.525 | .300 | 1.745 | 57 | 14.125 | .300 | 4.235 | | | |
| 3 28 | 6.875 | .300 | 2.060 | 58 | 14.175 | .300 | 4.255 | | | |
| 4 29 | 7.105 | .300 | 2.135 | 59 | 14.625 | .300 | 4.385 | | | |
| 5 30 | 7.375 | .300 | 2.210 | 60 | 14.875 | .300 | 4.465 | | | |
| 6 31 | 7.625 | .300 | 2.290 | 61 | 15.125 | .300 | 4.535 | | | |
| 7 32 | 7.875 | .300 | 2.360 | 62 | 15.375 | .300 | 4.615 | | | |
| 8 33 | 8.125 | .300 | 2.440 | 63 | 15.625 | .300 | 4.695 | | | |
| 9 34 | 8.375 | .300 | 2.515 | 64 | 15.875 | .300 | 4.765 | | | |
| 10 35 | 8.625 | .300 | 2.585 | 65 | 16.125 | .300 | 4.825 | | | |
| 11 36 | 8.875 | .300 | 2.660 | 66 | 16.375 | .300 | 4.915 | | | |
| 12 37 | 9.125 | .300 | 2.735 | 67 | 16.625 | .300 | 4.985 | | | |
| 13 38 | 9.375 | .300 | 2.815 | 68 | 16.875 | .300 | 5.065 | | | |
| 14 39 | 9.625 | .300 | 2.895 | 69 | 17.125 | .460 | 7.87 | | | |
| 15 40 | 9.875 | .300 | 2.965 | 70 | 17.375 | .440 | 7.64 | | | |
| 16 41 | 10.125 | .300 | 3.045 | 71 | 17.625 | .300 | 5.28 | | | |
| 17 42 | 10.375 | .300 | 3.115 | | | | | | | |
| 18 43 | 10.625 | .300 | 3.195 | | | | | | | |
| 19 44 | 10.875 | .300 | 3.265 | | | | | | | |
| 20 45 | 11.125 | .300 | 3.335 | | | | | | | |
| 21 46 | 11.375 | .300 | 3.415 | | | | | | | |
| 22 47 | 11.625 | .300 | 3.485 | | | | | | | |
| 23 48 | 11.875 | .300 | 3.565 | | | | | | | |
| 24 49 | 12.125 | .300 | 3.635 | | | | | | | |
| 25 50 | 12.375 | .300 | 3.715 | | | | | | | |
| 26 51 | 12.625 | .300 | 3.785 | | | | | | | |
| 27 52 | 12.875 | .300 | 3.865 | | | | | | | |
| 28 53 | 13.125 | .300 | 3.935 | | | | | | | |
| 29 54 | 13.375 | .300 | 4.015 | | | | | | | |
| 30 55 | 13.625 | .300 | 4.095 | | | | | | | |

$$\Sigma rL = 163.55$$

31 item 26: $285 \times 0.08 = 28 \times 0.08 \times 0.08 \times 1.938 = 0.224^{16}$

32 item 27: $= 28 \times 0.08 \times 0.08 \times 1.745 = 0.211^{16}$

33 163.55

34 $163.55 + 0.224 + 0.211 = 163.985$

35

36 TOTAL WEIGHT OF MODEL: $104.3 + 73.5 = 177.8^{16}$

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~~SECRET~~STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL4-1-5 WEIGHT OF MODEL COMPONENTS

Weight of ribs

$$\text{Side area: } \frac{7.5}{2} (.82 + 1.45) + (.95 \times 1.45) + \frac{.625}{2} (.65 + .82) =$$

$$8.5 + 1.375 + .46 = 10.338 \text{ in}^2$$

$$\text{Weight per rib: } .283 \times 10.338 \times .30 = .887 \text{ lb}$$

Total weight of ribs: 24 ribs:

$$.887 \times 24 = 21.30 \text{ lb}$$

4-1-6 TOTAL WEIGHT OF MODEL.

TOTAL WEIGHT OF MODEL WITHOUT DEDUCTION OF HOLES:

$$177.8 + 21.30 = 199.1 \text{ lb}$$

The holes will remove about 10 lb. However, instrumentation inside the model will add to the total and we can expect other variations due to tolerances etc...

TOTAL WEIGHT OF THE MODEL IS TAKEN AT: 200 lb

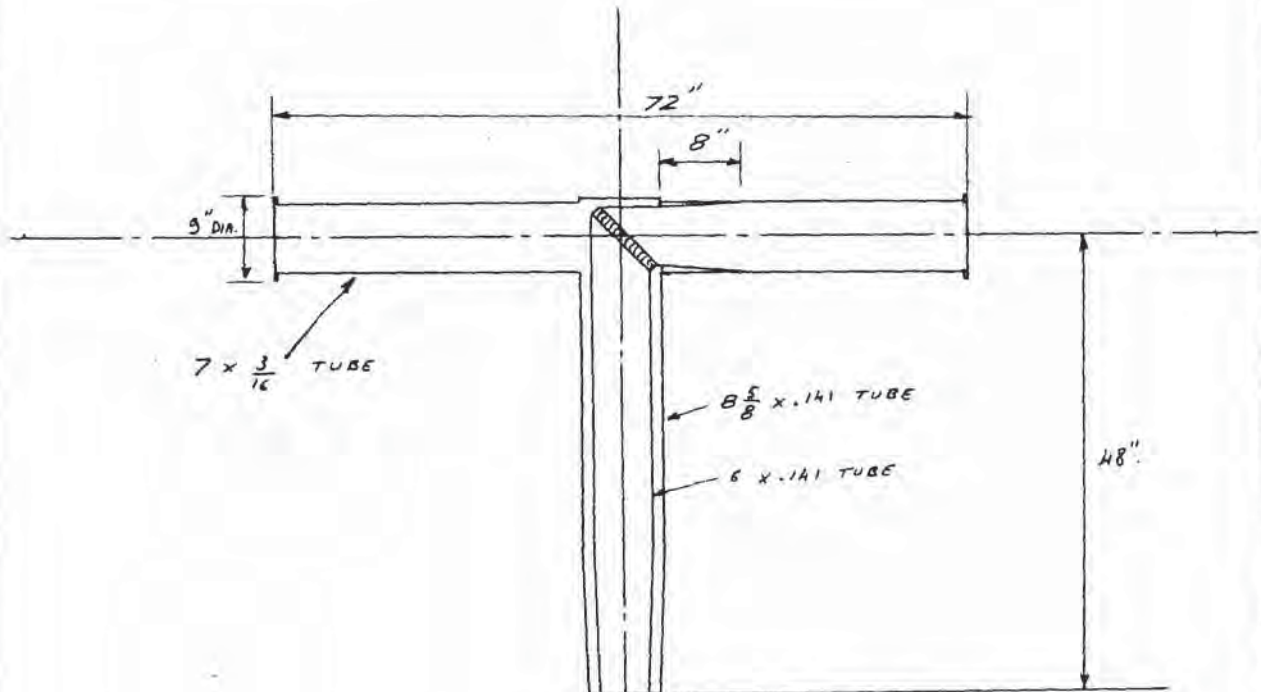
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -APPENDIX A - CALCULATION OF WEIGHT.A-2 - WEIGHT OF MODEL SUPPORT STRUCTURE.A-2-1 - MAIN TUBES.

Weight of steel pipe: Ref. ARMCO Welded Steel Pipe Catalog.

| O.D. | WALL THK. | WEIGHT/ft. |
|--------|-----------|---------------------|
| 6" | .141" | 8.80 ^{lb} |
| 6.625" | .141" | 12.74 ^{lb} |

Tube $7 \times \frac{3}{16}$ is available from stock; item: MT. 1015
cold drawn seamless tube.

Weight per foot at $.283 \frac{lb}{in^3}$

$$.283 \times 12 \times \frac{\pi}{4} (7^2 - 6.625^2) = 13.32 \frac{lb}{ft.}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELAPPENDIX A - CALCULATION OF WEIGHT.A-2 WEIGHT OF MODEL SUPPORT STRUCTUREA-2-1 MAIN TUBES.Weight of horizontal main tube: $13.32 \frac{72}{12} = 80 \frac{16}{16}$ xWeight of $8 \frac{5}{8}$ Vertical tube: $12.74 \frac{48+8}{12} = 59.5 \frac{16}{16}$ xWeight of 6" Vertical tube: $8.80 \frac{48}{12} = 35.20 \frac{16}{16}$ xTapered entry to 6" tube: assume approx. equal to 1 ft. of
tube $6 \frac{5}{8}$ OD x .141 Wall: $9.74 \frac{16}{16}$ say. $10 \frac{16}{16}$ xWeight of cascade: assume $2 \frac{16}{16}$ x

End rings.

$$2 \times .283 \times .375 \times \frac{\pi}{4} (9^2 - 7^2) = 5.33 \frac{16}{16}$$
 x

Total weight of model mounting not including incidence arm and
gase mounting.

$$80 + 59.5 + 35.2 + 10 + 2 + 5.33 = 192 \frac{16}{16}$$
 xv

$$\text{Weight of vertical tubes: } 59.5 + 35.2 = 94.7 \frac{16}{16}$$

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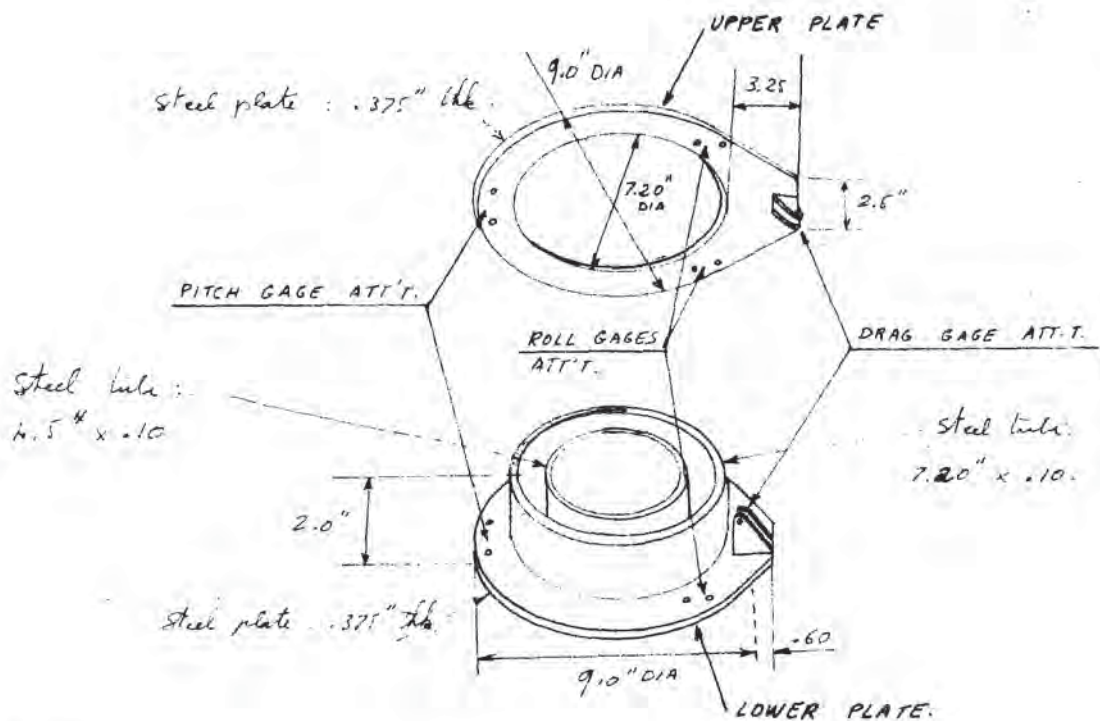
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELAPPENDIX A - CALCULATION OF WEIGHTA-2 WEIGHT OF MODEL SUPPORT STRUCTUREA-2-2LOAD GAGES ASS'Y.UPPER PLATEArea: measured on drawing: 37.68 in^2 Weight of plate: $.283 \times .375 \times 37.68 = 4.0 \text{ lb}$ LOWER PLATEArea measured on drawing: 28.18 in^2 Weight of plate: $.283 \times .375 \times 28.18 = 3.00 \text{ lb}$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELAPPENDIX A - CALCULATION OF WEIGHTA-2 WEIGHT OF MODEL SUPPORT STRUCTUREA-2-2.LOAD GAGES ASS'Y - CONT'D.

Tubes:

$$\text{Larger tube : Weight : } .283 \times 2.0 \frac{\pi}{4} (7.2^2 - 7.0^2) = 1.33^{16}$$

$$\text{Smaller tube : Weight : } .283 \times 2.5 \frac{\pi}{4} (4.5^2 - 4.1^2) = .62^{16}$$

Drag gage Brackets:

Weight estimated at 1^{16}

Total weight:

$$4 + 3 + 1.33 + .62 + 1 = 9.95^{16}$$

add 10% for welds, bolts etc...

$$9.95 \times 1.1 = 10.95^{16} \text{ say } 11^{16}$$

WEIGHT OF RING GAGES.GAGE A. 800¹⁶ RATED LOAD.

$$W = .283 \left[\frac{\pi}{4} (D^2 - d^2) b + 2 b_f t_f L_f + 2 b_p t_p L_p \right]$$

substituting $d = D - 2t$

$$W = .283 \left[\pi b t (D - t) + 2 b_f t_f L_f + 2 b_p t_p L_p \right]$$

$$= .283 \left[\left(\pi \times .625 \times .22 (3 - .22) \right) + (2 \times .50 \times .08 \times .55) + (2 \times .50 \times .20 \times 1.50) \right]$$

$$= .436^{16}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELAPPENDIX A - CALCULATION OF WEIGHTA-2 WEIGHT OF MODEL SUPPORT STRUCTUREA-2-2 LOAD GAGE ASS'YWEIGHT OF RING GAGES - CONT'DGAGES B & C : RATED LOAD : 350^{lb}

$$\begin{aligned}
 W &= .283 \left[\pi b t (D - t) + 2 b_f t_f L_f + 2 b_p t_p L_p \right] \\
 &= .283 \left[\left(\pi \times .50 \times .165 (3.0 - .165) \right) + (2 \times .375 \times .047 \times .55) + (2 \times .50 \times .20 \times 1.50) \right] \\
 &= .298 \frac{lb}{\text{per gage}} \quad \rightarrow 596 \frac{lb}{\text{for the 2 gages}} \quad \times
 \end{aligned}$$

GAGE D - : RATED LOAD : 150^{lb}

$$\begin{aligned}
 W &= .283 \left[\pi b t (D - t) + 2 b_f t_f L_f + 2 b_p t_p L_p \right] \\
 &= .283 \left[\left(\pi \times .40 \times .10 (2 - .10) \right) + (2 \times .25 \times .030 \times .35) + (2 \times .375 \times .375 \times .50) \right] \\
 &= .109 \frac{lb}{\text{per gage}} \quad \times
 \end{aligned}$$

TOTAL WEIGHT OF GAGES:

$$\begin{aligned}
 .436 + .596 + .109 &= 1.141 \frac{lb}{\text{per gage}} \\
 \text{add 10\% for bolts heads, wiring etc:} \\
 1.141 \times 1.1 &= \approx 1.3 \frac{lb}{\text{per gage}} \quad \times
 \end{aligned}$$

Total weight of vertical pipes:

$$94.7 + 11.0 + 1.3 = 107 \frac{lb}{\text{total}}$$

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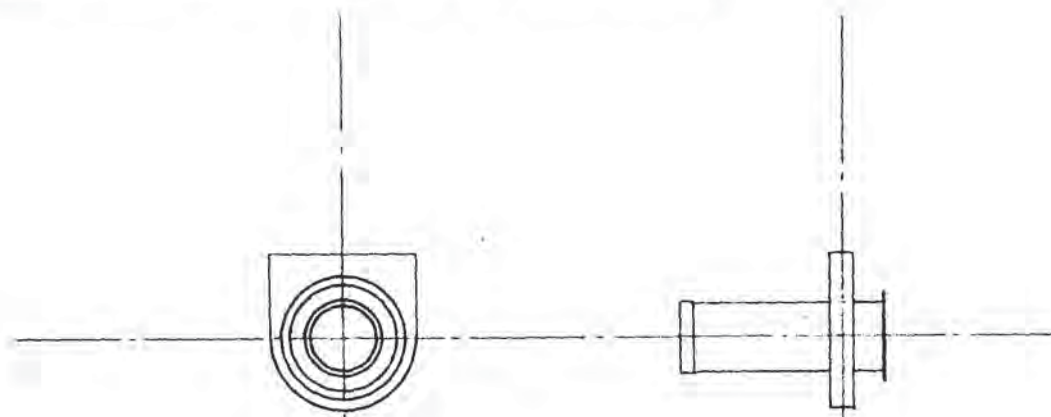
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELAPPENDIX A - CALCULATION OF WEIGHTA-2 WEIGHT OF MODEL SUPPORT STRUCTURE.A-2-3.WEIGHT OF ATTACHMENT TO BALANCE STRUTS.BALL-BEARING. SKF- 6238-M

Weight of balls: $V = \frac{\pi D^3}{6}$

$$15 \times .283 \times \pi \frac{1.875^3}{6} = 14.68^{16}$$

Outer race:

Mean dia: $13.38 - .70 = 12.68"$

Sectional area: $2.16 \times .70 = 1.51 \text{ in}^2$

Weight: $.283 \times 1.51 \times 12.68 \pi = 17.12^{16}$

Inner race:

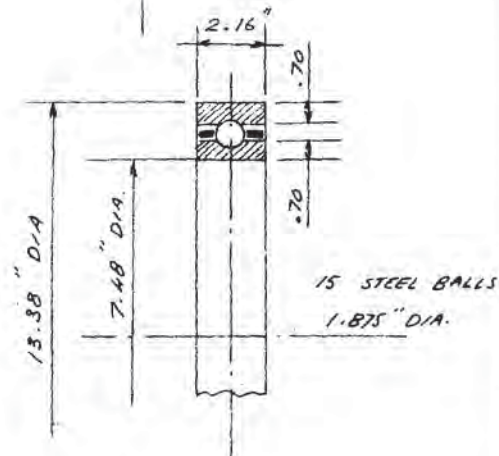
Mean dia: $7.48 + .70 = 8.18"$

Sectional area: $2.16 \times .70 = 1.51 \text{ in}^2$

Weight: $.283 \times 1.51 \times 8.18 \pi = 10.95^{16}$

Weight of Bearing: $14.68 + 17.12 + 10.95 = 42.75^{16}$

Note: By not removing the weight of the grooves, that of the retainers is taken care off.



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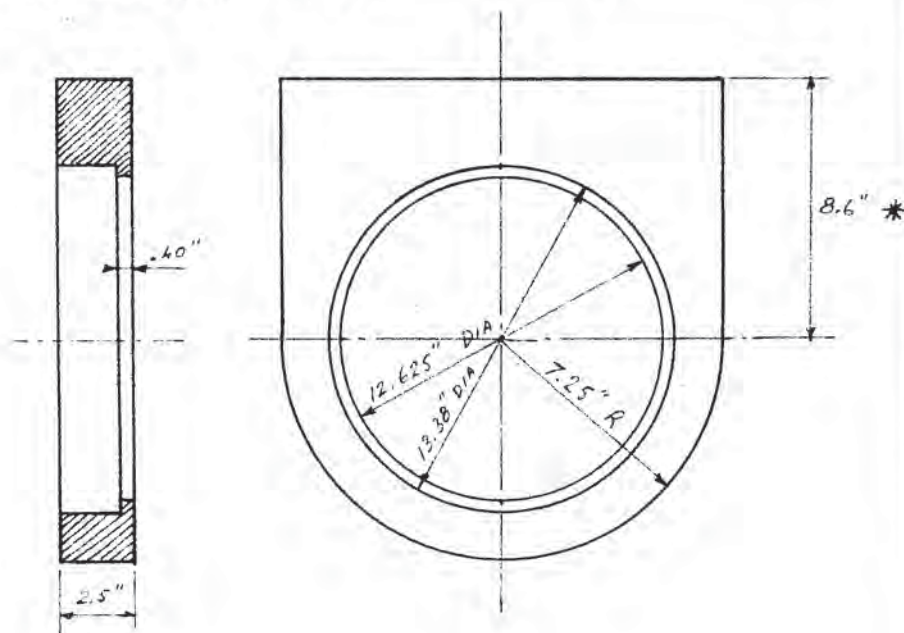
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELAPPENDIX A - CALCULATION OF WEIGHT.A-2 WEIGHT OF MODEL SUPPORT STRUCTUREA-2-3ATTACHMENT TO BALANCE STRUTS. CONT'D.BEARING HOUSING.

Side area:

$$(14.5 \times 8.6) + \left(7.25^2 \frac{\pi}{2}\right) - \left(13.38^2 \frac{\pi}{4}\right) = 124.8 + 83 - 141 = 66.8 \text{ in}^2$$

$$\text{Weight: } 66.8 \times 2.5 \times .283 = 47.3 \text{ lb}$$

Retention ring:

$$.283 \times 4.0 \times \frac{\pi}{4} (13.38^2 - 12.625^2) = 1.70 \text{ lb}$$

$$\text{Total weight: } 47.3 + 1.70 = 49 \text{ lb}$$

* NOTE

Dimension 8.6" is now 17.28". However, a number of large holes have been cut in the rectangular part of this component. Exact weight has not be computed again.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELAPPENDIX A - CALCULATION OF WEIGHTA-2 WEIGHT OF MODEL SUPPORT STRUCTUREA-2-3ATTACHMENT TO BALANCE STRUTS - CONT'D.TUBE, FLANGE & OTHER RINGS.

Tube length: 21.50" $7 \times \frac{3}{16}$ Tube Steel:
 weight: 13.32 $\frac{lb}{ft}$

Tube weight: $13.32 \times \frac{21.5}{12} = 23.9 \frac{lb}{ft}$

Flange: 5.33 $\frac{lb}{ft}$ (Ref. page B-)

Ball bearing mounting ring, assumed 12 $\frac{lb}{ft}$

End rings, assumed 6 $\frac{lb}{ft}$

Total weight: $23.9 + 5.33 + 12 + 6 = 47.23 \frac{lb}{ft}$

add 10% for welds, bolts, etc:

$47.23 \times 1.10 = \underline{\underline{52 \frac{lb}{ft}}}$

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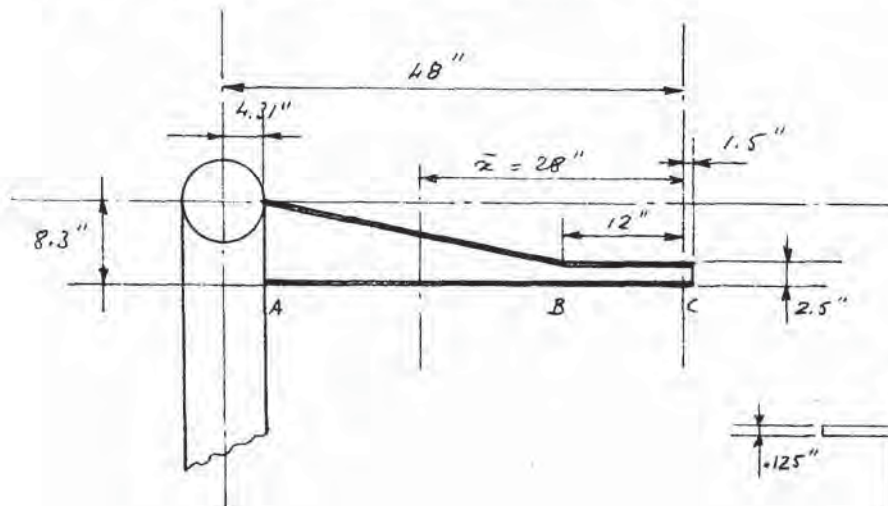
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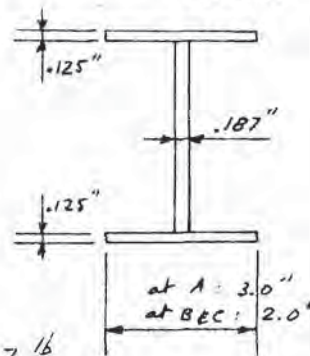
APPENDIX A - CALCULATION OF WEIGHT

A-2 WEIGHT OF MODEL SUPPORT STRUCTURE

A-2-4 - INCIDENCE CONTROL ARM.



TYPICAL ARM SECTION



FLANGES

Total length of tapered flanges: $31.7 + 32.3 = 64"$ Weight of tapered flange: $64 \times 2.5 \times .125 \times .283 = 5.67^{lb}$ Total length of constant width flange: $(12 + 1.5) 2 = 27"$ Weight of constant width flange: $27 \times 2 \times .125 \times .283 = 1.91^{lb}$

WEB

Rectangular part: Side area: $(2.5 - .25) (12 + 1.5) = 30.4 \text{ in}^2$
weight: $30.4 \times .187 \times .283 = 1.6^{lb}$ Trapezoidal part: Side area: $\left(\frac{8.05 + 2.25}{2} \right) \frac{48 - 12 - 4.31}{2} = 163.5 \text{ in}^2$
weight: $163.5 \times .187 \times .283 = 8.65^{lb}$ Weight of web: $(163.5 + 30.4) \times .187 \times .283 = 10.25^{lb}$ Total weight of arm: $10.25 + 1.91 + 5.67 = 17.83^{lb}$ then $\bar{x} = \frac{(33 \times 14.32) + (6 \times 3.51)}{17.83} = 28"$ Weight of rear balance strut connecting link: $\approx 3.5^{lb}$ Total weight of arm: $17.83 + 3.5 = 21.35$ say 21.50^{lb} add 10% for welds: 23.70^{lb} say 24.0^{lb}

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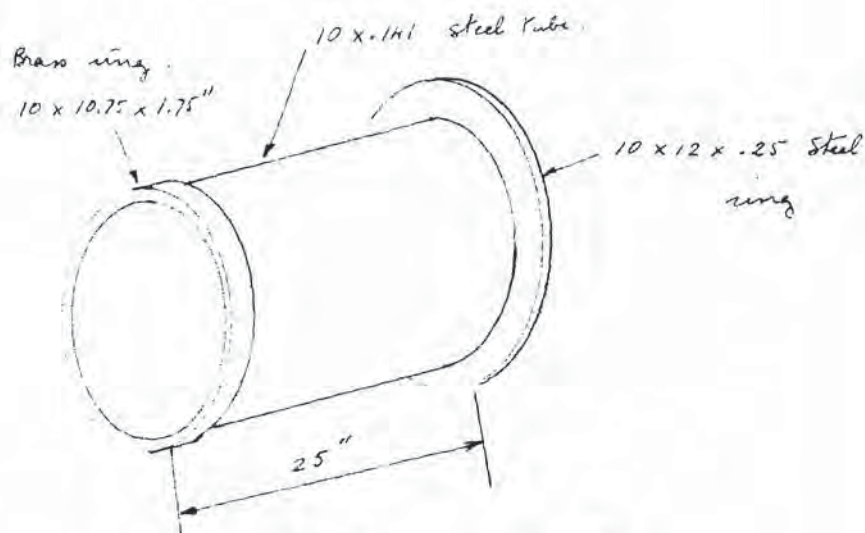
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.APPENDIX A - CALCULATION OF WEIGHTA-3 WEIGHT OF FAIRING.A-3-1FAIRING - OUTER SECTION.

Weight of 10" tube: Ref. Grunco catalog 14.81 $\frac{16}{ft.}$

Weight of tube: $14.81 \times \frac{25}{12} = 30.9 \frac{16}{ft.}$

Weight of steel ring:
 $.283 \times .25 \times \frac{\pi}{4} (12^2 - 10^2) = 2.44 \frac{16}{ft.}$

Weight of brass ring:
 $.306 \times 1.75 \times \frac{\pi}{4} (10.75^2 - 10^2) = 6.53 \frac{16}{ft.}$

Total weight: $30.9 + 2.44 + 6.53 = 39.87 \frac{16}{ft.}$

add 10% for welds, bolts, etc....

$39.87 \times 1.10 = 43.85 \frac{16}{ft.}$

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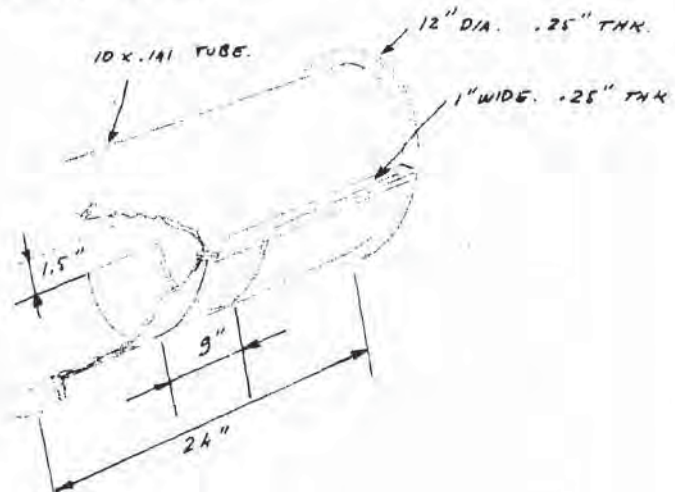
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELAPPENDIX A - CALCULATION OF WEIGHTA-3 WEIGHT OF FAIRINGA-3-2FAIRING - CENTER SECTION - CYLINDRICAL PART.

Weight of tube: Ref. ARMCO CATALOG. Size 10 x .141. $14.81 \frac{lb}{ft}$

Weight of uncut tube: $14.81 \frac{24}{12} = 29.62 \frac{lb}{ft}$

Weight removed by cut. arc: 165°

$$14.81 \frac{9}{12} \frac{165}{360} = 5.10 \frac{lb}{ft}$$

Total weight of tube: $29.62 - 5.10 = 24.52 \frac{lb}{ft}$

Weight of rings: $2 \times .283 \times \frac{\pi}{4} (12^2 - 10^2) .25 = 4.87 \frac{lb}{ft}$

Weight of side strips: $4 \times .283 \times 1.0 \times .25 \times 23.5 = 6.65 \frac{lb}{ft}$

Total weight of component:

$$24.52 + 4.87 + 6.65 = 36.04 \frac{lb}{ft}$$

add 10% for welds, bolts, etc: $36.04 \times 1.1 = 39.7 \frac{lb}{ft}$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

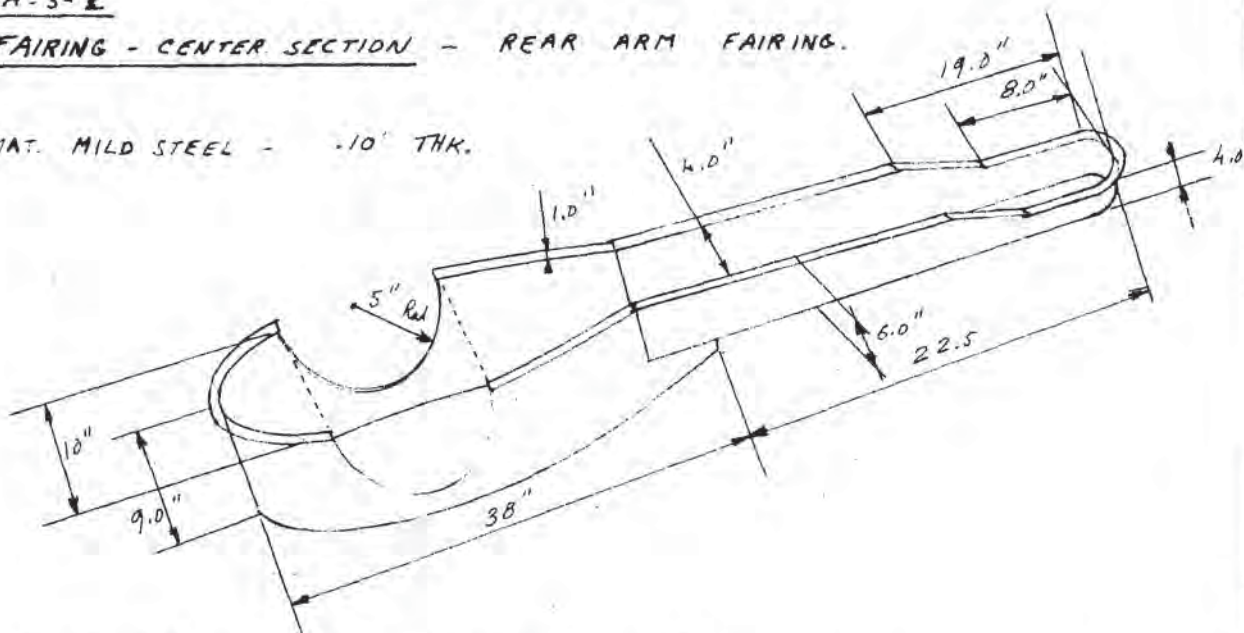
APPENDIX A - CALCULATION OF WEIGHT

A-3 WEIGHT OF FAIRING

A-3-2

FAIRING - CENTER SECTION - REAR ARM FAIRING.

MAT. MILD STEEL - .10" THK.



Developed length of streamlined part: 82"

Lateral area of developed part: $(82 \times 9.0) - \pi \times 5^2 = 738 - 78.5$
 $= 659.5 \text{ in}^2$

Arm fairing:

Sides: area: $6.0 (2 \times 22.5 + 4.0) = 294 \text{ in}^2$ Bottom: $22.5 \times 6 = 135 \text{ in}^2$

Edge: 1.0" wide: total length measured on drawing 105"

Area: 105 in^2 Cover plates: Front plate $\approx \frac{1}{2}$ circle: rad. 3.0" 14 in^2 Rear plate $\approx \frac{25 \times 12}{2} = 150 \text{ in}^2$ + $25 \times 6 = 150 \text{ in}^2$ Total area of plate: $659.5 + 294 + 135 + 105 + 150 + 150 = 1493.5 \text{ in}^2$ Weight of plate: $.283 \times .10 \times 1493.5 = 42.3 \text{ lb}$

add 10% for welds, bolts, etc:

 $42.3 \times 1.1 = 46.50 \text{ lb}$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELAPPENDIX A - CALCULATION OF WEIGHTA-3 WEIGHT OF FAIRING.A-3-2.FAIRING - CENTER SECTION - ALUMINUM PART.

MAT. 24 ST. AL. ALL .064" THK @ .10 $\frac{lb}{in^3}$

Developed length of contour: 82"

Lateral area of sheet:

$$82 \times 40 = 3280 \text{ in}^2$$

$$\text{Volume: } 3280 \times .064 = 210 \text{ in}^3$$

Weight of sides:

$$210 \times .10 = 21 \text{ lb}$$

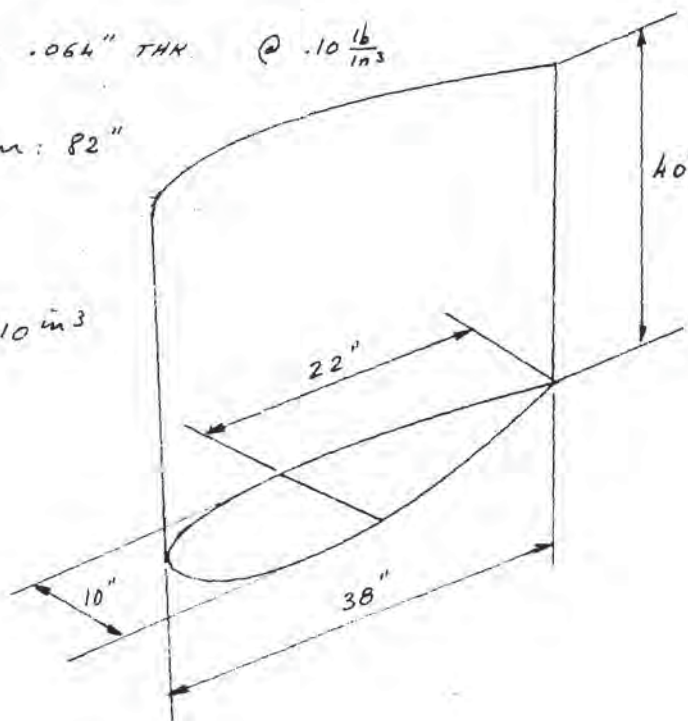
Bottom part:

approx area:

$$10 \times \frac{22}{2} = 110 \text{ in}^2$$

$$\text{Weight: } .10 \times .064 \times 110 = .70 \text{ lb}$$

$$\text{Total weight of aluminum fairing: } 21 + .70 = 21.70 \text{ lb}$$



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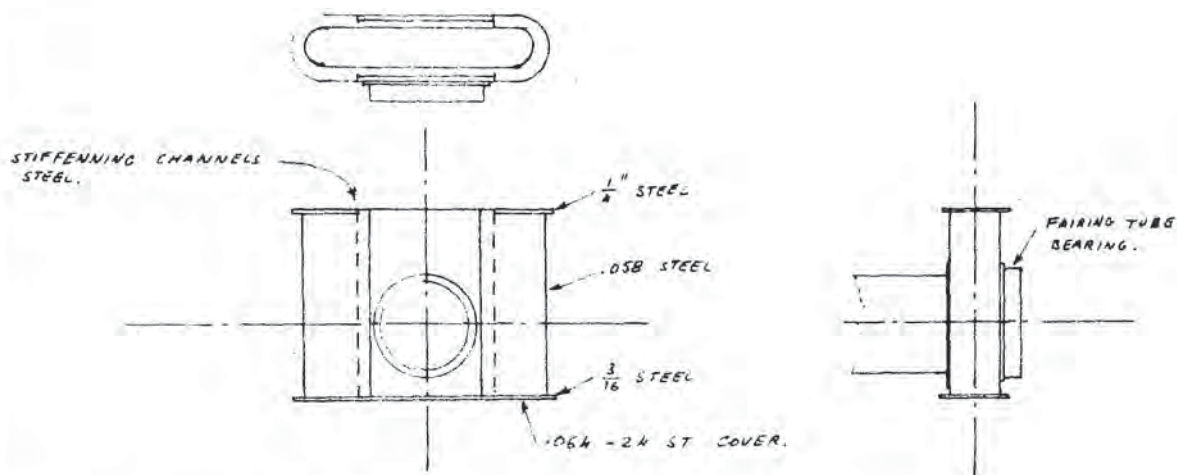
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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELAPPENDIX A - CALCULATION OF WEIGHTA-3 WEIGHT OF FAIRINGA-3-3ATTACHMENT TO BALANCE STRUTS - FAIRING -LOWER BORDER. $\frac{3}{16}$ STEEL.

thickness: .187" - width: .875" mean length: 54"

weight: $.283 \times .187 \times .875 \times 54 = 2.5 \frac{1}{16}$ xUPPER BORDER. $\frac{1}{4}$ STEEL.

thickness: .250" width: .875" mean length: 31.2"

Weight: $.283 \times .25 \times .875 \times 31.2 = 1.93 \frac{1}{16}$ xSTIFFENING CHANNELS.Thickness: .050" - developed width: 2.4" length: $19 \times 4 = 76$ "Weight: $.283 \times .050 \times 2.4 \times 76 = 2.99 \frac{1}{16}$ x

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELAPPENDIX A - CALCULATION OF WEIGHTA-3 WEIGHT OF FAIRINGA-3-3ATTACHMENT TO BALANCE STRUTS - FAIRING - CONT'D.LOWER COVER PLATE. .064" 24 ST.

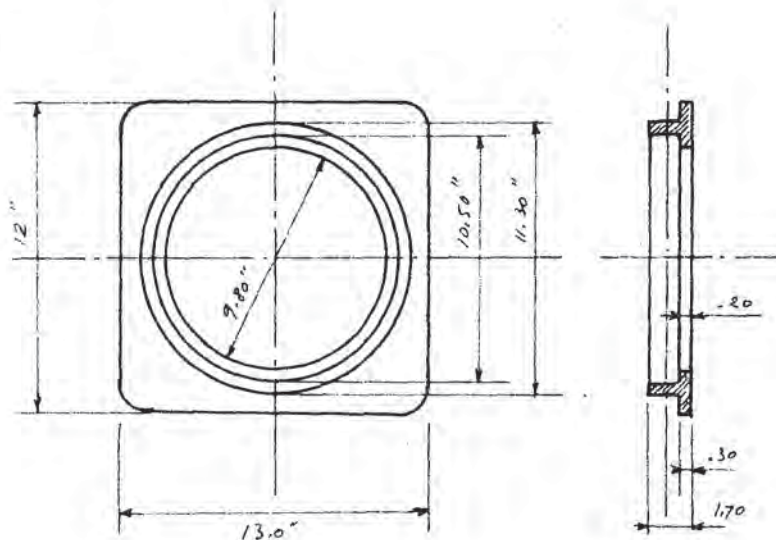
Thickness: .064" - width: 5.5" mean length: 11.60" x 2

Weight: $.10 \times .064 \times 5.5 \times 23.2 = .81^{16}$ xFRONT & REAR SHEETING. .058" STEEL

Thickness: .058" developed width: 16.8" length: 19"

Weight: $2 \times .283 \times .058 \times 16.8 \times 19 = 10.5^{16}$ xSIDE SHEETING. .072" STEEL.Thickness: .072" side area: $(13 \times 13) - \left(\frac{\pi}{4} 10^2\right) = 169 \text{ in}^2$ Weight: $2 \times .283 \times .072 \times 169 = 6.9^{16}$ xFAIRING TUBE BEARING.

MAT. STEEL.



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELAPPENDIX A - CALCULATION OF WEIGHTA-3 WEIGHT OF FAIRING.A-3-3ATTACHMENT TO BALANCE STRUTS - FAIRINGS - CONT'D.FAIRING TUBE BEARING - CONT'D.

Plate thickness: .30

$$\text{Area: } (12 \times 13) - \frac{\pi}{4} (10.50)^2 = 69 \text{ in}^2$$

$$\text{Weight: } .283 \times .30 \times 69 = 5.86 \text{ lb} \quad x$$

Cylinder:

$$\text{Weight: } .283 \frac{\pi}{4} (11.30^2 - 10.50^2) 1.50 = 6.02 \text{ lb} \quad x$$

Retainer ring

$$\text{Weight: } .283 \frac{\pi}{4} (10.50^2 - 9.5^2) .20 = .622 \text{ lb} \quad x$$

Retainer ring - external:

$$\text{Weight: } .283 \frac{\pi}{4} (11.30^2 - 9.50^2) .187 = 1.33 \text{ lb} \quad x$$

$$\text{Total weight: } 5.86 + 6.02 + .622 + 1.33 = 13.83 \text{ lb}$$

add 10% for bolts, welds, etc.

$$13.83 \times 1.10 = 15.25 \text{ lb} \quad x x$$

TOTAL WEIGHT OF FAIRING.

$$2.5 + 1.93 + 2.99 + .81 + 10.5 + 6.9 + 13.83 = 39.46 \text{ lb}$$

add 10% for welds, bolts, etc:

$$1.10 \times 39.46 = 43.50 \text{ lb} \quad x x$$

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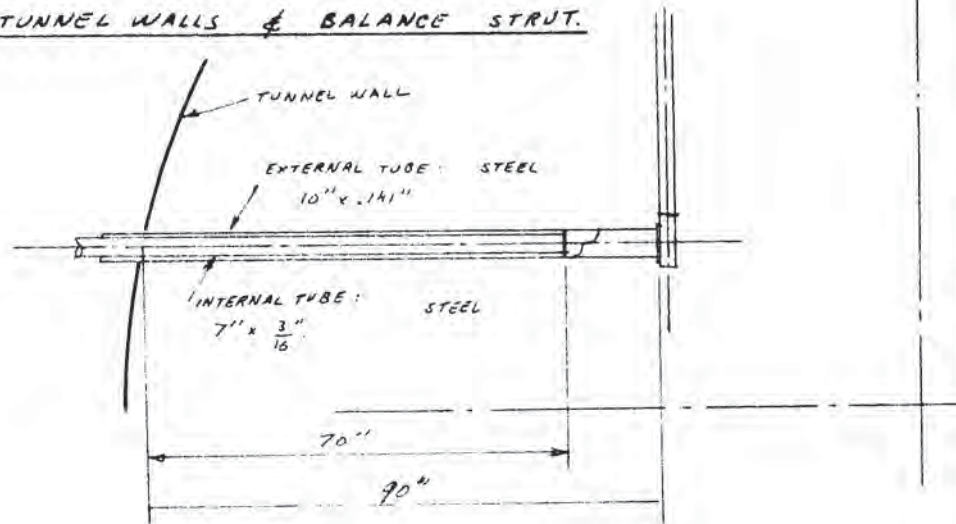
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SECRET**DECLASSIFIED** 207STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODELAPPENDIX A - CALCULATION OF WEIGHTA-3 WEIGHT OF FAIRINGA-3-HTUBES BETWEEN TUNNEL WALLS & BALANCE STRUT.

EXTERNAL TUBE: $14.81 \frac{lb}{ft}$

Weight: $\frac{90}{12} \times 14.81 = 111 \frac{lb}{ft}$

INTERNAL TUBE: $13.32 \frac{lb}{ft}$

Weight: $\frac{70}{12} \times 13.32 = 77.7 \frac{lb}{ft}$

TOTAL WEIGHT OF TUBES.

$111 + 77.7 = 188.7 \frac{lb}{ft}$

Assume $\frac{1}{2}$ the total weight is applied on the strut fairing + $10 \frac{lb}{ft}$ for miscellaneous parts:

$94.35 + 10 = 104.35$ say $105 \frac{lb}{ft}$ xx

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